ENGINEERING DRAWING

A TEXTBOOK FOR TECHNICAL SCHOOLS

SCHOOL TECHNOLOGY SERIES

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A TEXTBOOK FOR TECHNICAL SCHOOLS

By

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G. L. Sinha
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Foreword

IT IS a truism that we live in an age of technology. Our four successive Five Year Plans are all directed towards the development of a technological society. To this end, we have to train a multitude of technicians who will set up plants, design and produce machines, tools and implements to bring to fruition the well-considered plans of an informed leadership.

The National Council of Educational Research and Training is particularly concerned today with education at school level. Technology is one of the fourteen subject-fields in which the National Council, on the advice of its Central Committee on Educational Literature, is bringing out textbooks. In agreement with public feeling, and with the recent recommendations of the Education Commission Report, the Council is producing educational materials for vocationalized secondary schools. The present publication on engineering drawing is an earnest of its plan of work to provide these schools with model textbooks. This is one of four textbooks that have been and are being prepared by Professor K. B. Menon, Head of the Department of Electrical Engineering, Indian Institute of Technology, Kharagpur. Other books in the series are: (i) Elements of Electrical Engineering, (ii) Workshop Practice, and (iii) Elements of Mechanical Engineering.

Engineering Drawing is an introductory book for students in the higher classes of Indian secondary schools who offer Engineering as an elective subject and for students of specialized technical schools. The book will also be useful in the earlier stages of polytechnic diploma courses. The aim of the book is to present an overall view of major areas in the subject without entering into the specialized details required for advanced studies. Its purpose is to develop in the students an adequate skill in engineering drawing. The text is in simple English and all technical terms are carefully defined in the interest of clarity.

The National Council wishes to thank the authors of the book, namely, Dr. K. S. Rangasami, formerly Assistant Professor of Civil Engineering, Indian Institute of Technology, Kharagpur and now Head of the Department of Civil Engineering, Regional Engineering College, Rourkela; Dr. G. L. Sinha, Assistant Professor of Mechanical Engineering, Indian Institute of Technology, Kharagpur;

and Shri D. N. Sarbadhikari, formerly lecturer in Engineering at Hijli High School, Kharagpur. The Council is grateful to Professor K. B. Menon, Head of the Department of Electrical Engineering, Indian Institute of Technology, Kharagpur, and Chairman of the Panel for Textbooks in Technology for Secondary Schools. To the authorities and to Dr. S. R. Sen Gupta, Director, Indian Institute of Technology, Kharagpur, the Council is grateful for the facilities provided for the completion of this task.

The Council hopes that all students of technology at secondary level will benefit from this book. Suggestions from teachers and others interested in Engineering Drawing are welcome and will be considered when this book is revised.

L. S. Chandrakant

Preface

ENGINEERING DRAWING is an elementary book, in the School Technology Series published by the National Council of Educational Research and Training, New Delhi.

The book is intended as an introduction to engineering drawing for beginners in the age group 13-17 years, who are studying engineering as an optional subject in multipurpose higher secondary schools or for students in technical schools. It will also be useful to students of polytechnics who have no previous training in engineering drawing in their high schools. Simple language has been used, and each technical term defined when it first occurs. There is a glossary in Appendix II.

The aim of the book is (1) to present an overall view of the major areas of engineering drawing practice without entering into specialized details and (2) to train students to develop a moderate skill in making engineering drawing.

The book excludes complicated details and discusses only the essentials of a wide range of topics in engineering drawing.

The book generally conforms to the practice recommended by (1) IS: 696-1960 Code of Practice for General Engineering Drawing, and (2) IS: 962-1960 Code of Practice for Architectural and Building Drawings. These codes must be consulted for advanced details. The books in the bibliography (Appendix III) may be referred to for further study.

K. S. Rangasami
G. L. Sinha
D. N. Sarbadhikari

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CHAPTER 1

Introduction

1.1 Drawing—A Universal Language

Drawing may well be called a universal language. Nobody can possibly misunderstand what a particular drawing stands for. It is so unmistakable even when you make just a rough sketch of a dog or tree. In fact, man learnt to draw long, long before he learnt to write. Alphabets came fairly late in the history of civilization.

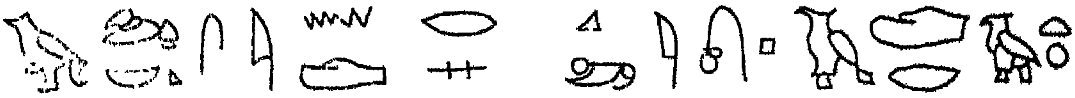
The ancient Egyptians practised a kind of "picture-writing", known as "hieroglyphics". Our cavemen forefathers who lived about 12,000 years ago, also had a taste for drawing. Quite a few specimens of their paintings are still to be found in old caves in certain parts of the world. In Altamira in Spain, for instance, there are many paintings, of animals like boars, oxen, horses and bisons. These pictures look fairly life-like and full of fight. Strange to say, the cavemen artists even used paint. Their paint seems to be a mixture of charcoal, oxide of managanese and some kind of oil.

Drawing, in fact, scores over language in a way. In the modern era, there are almost as many languages as there are countries in the world. Thus, language is actually a barrier between men of different countries. On the other hand, drawing is a universal language, easily understood by all, irrespective of their nationality.

If any student is asked to explain the arrangement of the rooms in his house, he will at once imagine the plan of the house and begin to sketch it. The average modern man very often sees plans, maps, sketches, graphs and charts in newspapers and newsreels and can understand them. Young students must learn, therefore, not only to read and understand drawings but also to make such drawings and sketches neatly and clearly.

1.2 Draughtsman and His Work, Relationship to the Craftsman and the Engineer

An engineer is one who designs or constructs machines, or public works, such as roads, bridges, railways and other



Hieroglyphics

structures. His designs are, generally speaking, in the form of rough sketches. They give the essential features of his machine or structure and may contain many symbols and abbreviations, whereas a craftsman is a skilled worker such as a a mechanic, mason or carpenter. It is craftsmen who actually construct or build the machine or other structures finally, under the supervision and instruction of the engineer.

The design drawings of the engineer may be incomplete in many common details and cannot be passed on to the workshops or the field engineer employing the craftsmen. Hence a draughtsman is employed to make the final, detailed and complete, neat drawings. These are known as working drawings or detailed drawings. These are prepared from the design drawings, in consultation with the engineer. Thus, a draughtsman makes the final drawings and conveys to the craftsman, the ideas of the engineer, in an easily understandable manner.

The engineer must assume full responsibility for the final machine or structure that he has conceived. He must be able to detect and correct the errors, if any, in the drawing. Hence it is essential for the engineer to acquire a thorough knowledge of what is called "Engineering Drawing" or "Technical Drawing". This in fact, is the language of the engineers.

PROBLEMS

1. Which do you think came first, drawing or writing ?
2. Do you like to see a picture of your pet dog or a written description of it?
3. Try to describe the figure of a dog in words and see if the same words may also be used to describe a cat or a fox. Is it not better to make sketches or pictures of the animals in order to understand their shape ?
4. What is a universal language ?
5. What are "hieroglyphics" ?
6. How did the ancient cavemen convey their information about their way of living ?
7. What is the name given to drawings that indicate the arrangement of the rooms in a building ?
8. What is the name given to drawings that show the relative positions of cities, roads, railway lines, rivers, mountains and seas ?
9. What is the difference between a sketch and a drawing ?
10. Describe some of the symbols used on maps ?
11. Who is an Engineer ?
12. Who makes the drawings required by the craftsman ?

CHAPTER 2

Drawing Instruments and Equipment—Their Characteristics and Correct Use

2.1 Know Your Tools

A skilled worker can hardly do a good job with poor tools. A draughtsman is no exception. Drawing instruments and equipment should be well-made and well-maintained. Each instrument or piece of equipment is meant for a certain job. Use your tools to do the job for which they have been designed. Remember that a good set of drawing instruments will last a life-time if used with proper care.

Care of tools :

(*a*) Keep each piece of equipment in a definite place so that you may find it handy. Put it back in its place when you have done with it.

(*b*) Replace your instruments in their box when they are not in use.

(*c*) Wipe your pens clean and keep pencils sharpened ready for instant use when required.

In this chapter, only the essential items of instruments and equipment required by a beginner are briefly described. The right technique for using them is best learnt by carefully observing the instructor's demonstration of the use of these tools. The student can, however, acquire skill in the use of tools, only by actually working with them, with care and interest.

A list of essential drawing instruments and equipment for students is as follows:

1. Pencils (HB, H to 4H).
2. Pencil pointers (sandpaper pad or file).
3. Drawing paper.
4. Tracing paper.
5. Adhesive tape or thumbtacks.
6. Drawing board.
7. T-square (Tee square).

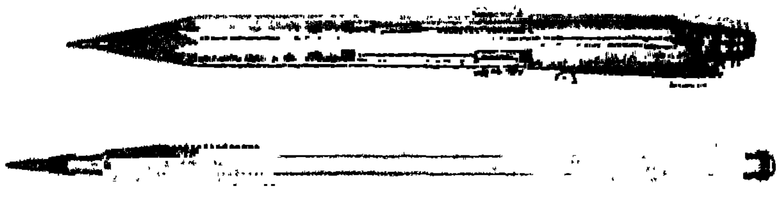


Fig. 2.0 Mechanical pencils

8. Set-square (triangles)
   —one with 45° angles, and another with 30° and 60° angles.
9. Protractor.
10. Scales.
11. Set of drawing instruments consisting of :
    (i) 10-15 cm. compasses with pen and pencil attachments and a lengthening bar.
    (ii) 10-15 cm. dividers.
    (iii) Two ruling pens.
    (iv) Three bow instruments—one bow pencil, one bow pen, and one bow dividers.
12. French curves (irregular curves).
13. Erasers.
14. Erasing shield.
15. Indian ink.
16. Lettering pens.

Other accessories assumed to be readily available with any student are : a pocket knife, a duster, and a cloth for wiping ink from pens.

2.2 Pencils—Types and Grades

Pencil leads are made of a mixture of graphite and clay. The two types of pencils most commonly used are :

(1) ordinary pencils,—i.e. pencil lead covered with wood, and

(2) mechanical pencils—These are pencil-shaped tubular devices which hold the pencil-lead by means of spring clamps. The advantage of the mechanical pencil is that its length remains constant ; also there is no wood covering to cut away to expose the writing point.

Pencil leads are available in eighteen grades of hardness ranging from very soft (7B) to very hard (9H) grade, thus : 7B, 6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H and 9H.

The grade of pencil to be used depends on several factors, namely, the type of line desired, the kind of paper used, the humidity, the pressure used and personal preference of the draughtsman. Soft pencils make the drawing smudgy, while hard pencils leave a groove if the line is erased. In general, hard pencils (4H-6H) should be used with light pressure for drawing construction lines (i.e. trial working lines) or layout work where accuracy is required. Object lines may be finished in H or 2H pencils. H or HB pencils may be used for lettering and freehand sketching. The right pencil, however, is chosen by a few trials.

2.3 Pencil Pointer

A sandpaper pad for a flat smooth file may be used for making the required type of points.

The conical point as in Fig. 2.1a is preferred for general use. Some draughtsmen prefer the wedge point as in Fig. 2.1b for drawing straight lines. The compass lead is sharpened on one side only as shown in Fig. 2.1c.

Pencil lines should be sharp and uniform in thickness. The pencil should be held in a vertical plane at an inclination of about 60° to the horizontal in the direction in which the line is drawn.

2.4 Drawing Paper

Drawing paper may be cream white or buff in colour. Heavy or hard surface papers are used for high quality work.

The following are the Indian Standard sizes of drawing paper (IS : 696-1960) :

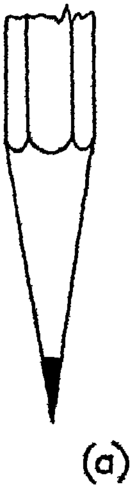


Fig. 2.1a Conical point

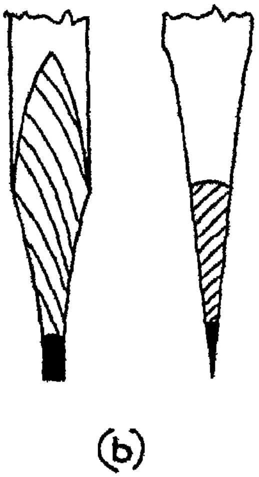


Fig. 2.1b Wedge point

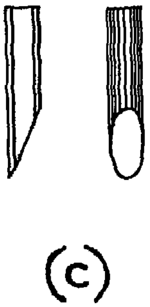
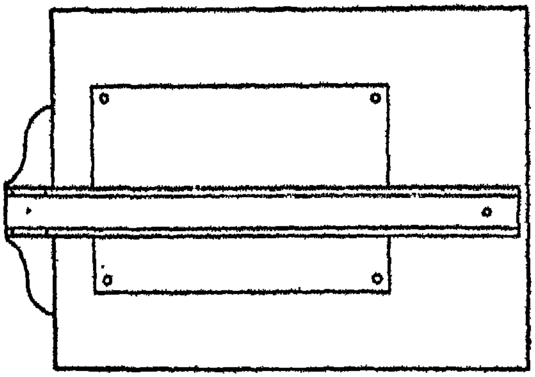


Fig. 2.1c Compass lead point

Designation	Trimmed Size mm.	Untrimmed Size (minimum) mm.
A0	841 × 1,189	880 × 1,230
A1	594 × 841	625 × 880
A2	420 × 594	450 × 625
A3	297 × 420	330 × 450
A4	210 × 297	240 × 330
A5	148 × 210	165 × 240

Drawing paper should be fastened to the drawing board close to the left working edge and also close to the upper working edge of the drawing board. The top edge of the drawing paper is lined up parallel to the upper edge of the T-square. The corners of the drawing paper are then pinned down with thumbtacks, Fig. 2.2, or fixed with adhesive tape to the drawing board, Fig. 2.3b.



Fig, Use 2.2 of thumbtacks

2.5 Tracing Paper

Tracing paper is a transparent paper upon which pencil or ink tracing of the original drawing is made. The tracing is used for reproducing copies of the original drawing by the blueprinting process.

2.6 Adhesive Tape or Thumbtacks

Adhesive tape or thumbtacks are used for fastening the drawing paper to the drawing board. Adhesive tape is also known as *cello-tape, Scotch tape* or *drafting tape* and is available in rolls. The tape does not dry out quickly and may be used a number of times. Adhesive tape has many advantages over thumbtacks. The tape can be used against any surface, for instance, glass. The tape does not damage the drawing board.

2.7 Drawing Board

Drawing boards are usually made of some soft wood such as blue pine, fir, cypress, oak or benteak. The board is made of narrow strips glued together edge to edge and mounted on transverse battens. There are grooves cut at the bottom of the strips to allow for expansion and contraction without warping the working surface, Fig. 2-3(a). The top surface is the working surface which should be smooth and plane.

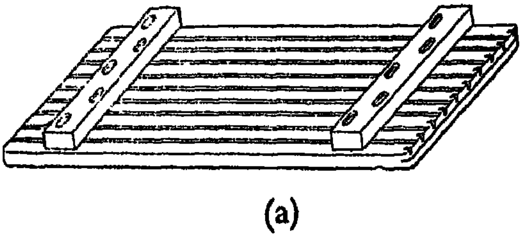


Fig. 2.3(a) Bottom view of drawing board

The drawing board has a straight working edge on the left side. This is usually made of a hard wood such as ebony or rose wood ; or it may be made of aluminium or plastic. The working edge is used for guiding the T-square for drawing horizontal lines, Fig. 2-3(b).

Drawing boards are available in different sizes ranging from 500 × 350 mm. to 1500 × 1000 mm.

The straight working edge of the board may be checked with a straight edge of the T-square. The two edges are placed in contact in a vertical plane against a source of light. If the edge of the board is straight, the edge of the T-square will be in contact with the edge of the board for its entire length. If the edge of the board is defective it should be corrected by planing or sandpapering.

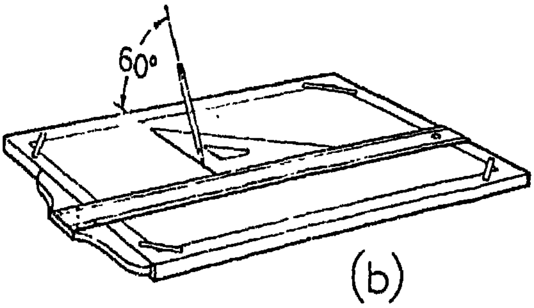


Fig. 2.3(b) Working edge guiding T-square

2.8 T-Square

The T-Square gets the name from its shape. The name is also written as *tee square.* It consists of a long, straight strip, *the blade*, and a short straight strip, *the head*, Fig. 2.4. The upper edge of the blade and the inner edge of the head are the working edges. The edges should be straight and be at right angles to each other. T-Squares may be made of wood, stainless-steel or rigid transparent plastics.

The straightness of the working edge of a T-Square can be tested as follows. Draw a straight line along the full length of the edge and then turn the T-Square over and draw the line again with the same edge of the T-Square. If the two lines coincide, the edge is straight. If the lines do not coincide, the error is half the size of the space between the two lines. This error must be corrected carefully, by planing or sandpapering, before the T-Square is used.

To keep a T-Square edge true, when it is not in use, it should be hung up by

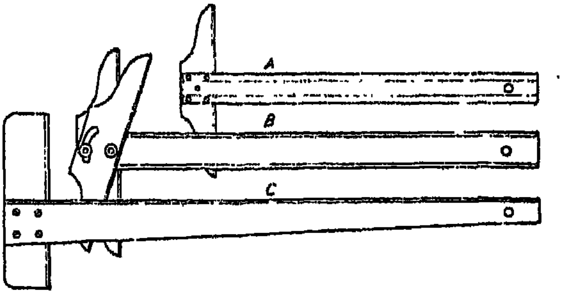


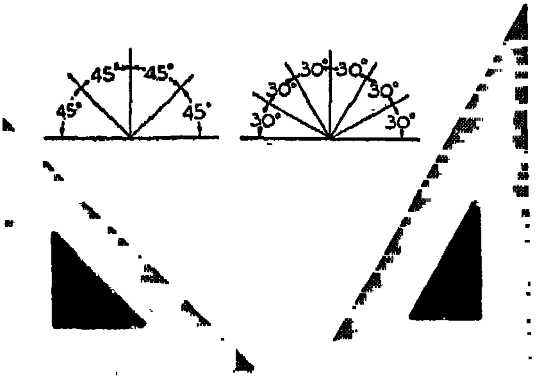
Fig. 2.4 T-square

means of the hole towards the end of the blade ; or it may be laid down on a flat surface.

2.9 Triangles (Set-Squares)

The most common triangles are those with the 45 degree and the 30-60 degree angles, Fig. 2.5. They are available in various sizes. A 20-30 cm. *side triangle* is a good size to use. Both triangles have one 90 degree angle. These are usually made of transparent plastics now-a-days. Some triangles have bevelled edges to make it easy for inking.

By means of the two triangles used in combination with the T-Square any angle which is a multiple of 15 degrees may be drawn as shown in Fig. 2.6.



(a) 45°TRIANGLE (b) 30°x60°TRIANGLE

Fig. 2.5 Triangles (set-squares)

2.10 Protractor

The protractor is used for laying out and measuring angles. It is usually made of transparent plastic in the form of a semicircle, Fig. 2.7. The semicircle is divided into degrees or even smaller divisions.

Protractors in the form of full circle or rectangle are also available.

2.11 Scale

Scales are used to mark off distances on drawings. Scales may be enlarging scales or full-size scales or reducing scales. The standard scales used are given in the next chapter. Scales may be made of cardboard, wood, stainless steel or opaque plastic. They may be flat or triangular in section. A triangular scale has the advantage of having eleven scale in one piece.

It is usual practice to indicate on the drawing only full-size dimensions of the object without regard to the scale used in making the drawing.

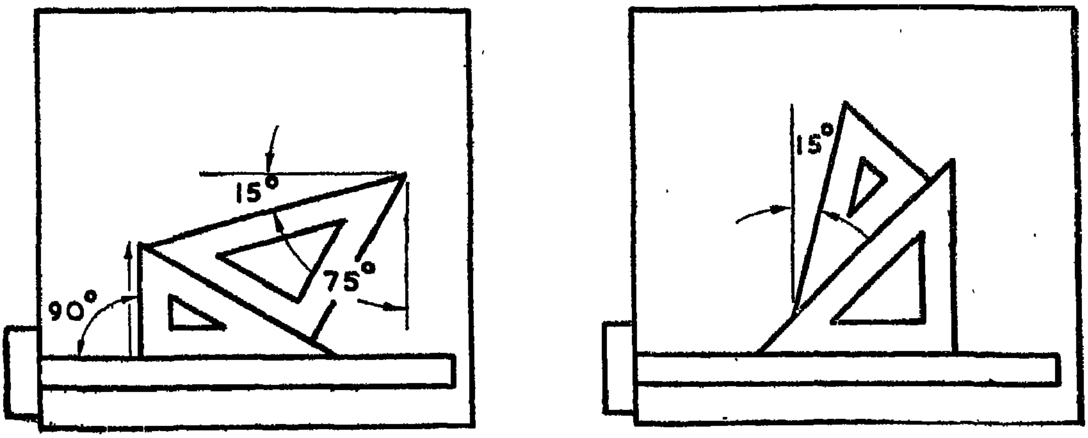


Fig. 2.6 Multiples of 15°, with 30° and 45° triangles

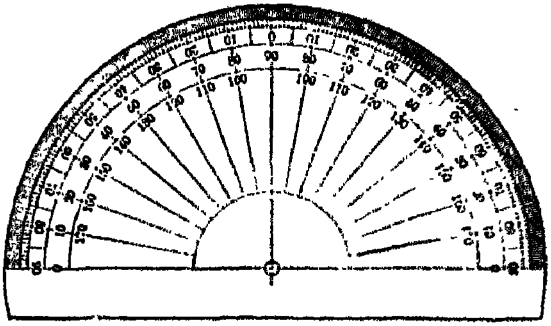


Fig. 2.7 Protractor

2.12 Set of Drawing Instruments

Drawing instruments are generally available in "sets" in velvet lined cases. A set consists of the following essential instruments as shown in Fig. 2.8.

1. Compasses with a pencil lead attachment, a pen attachment and an extension bar.
2. Dividers.
3. Bow pencil.
4. Bow dividers.
5. Bow pen.
6. Ruling pen.

These are delicate instruments, and should be handled carefully.

Some compasses and dividers have a hairspring for minute adjustments. The lengthening bar may be used to increase the radius of the compasses. The compasses are also known as the *compass* according to the American practice.

The compass is used for drawing circles and circular arcs. For drawing pencil circles accurately, the lead point should be sharpened as shown in Fig. 2-1c. When drawing ink circles with pen attachment, it is important to see that the pen point is approximately perpendicular to the plane of the paper. The height of the pivot of the compass from the pencil point should be about 1-2 mm, less than that from the needle point of the other leg.

The dividers are used to divide curved or straight lines into a number of equal parts (by trial-and-error method) or to transfer measurements.

The bow instruments (pencil, pen or dividers) are used when the arc radius is less than about 25 mm. Fine adjustment

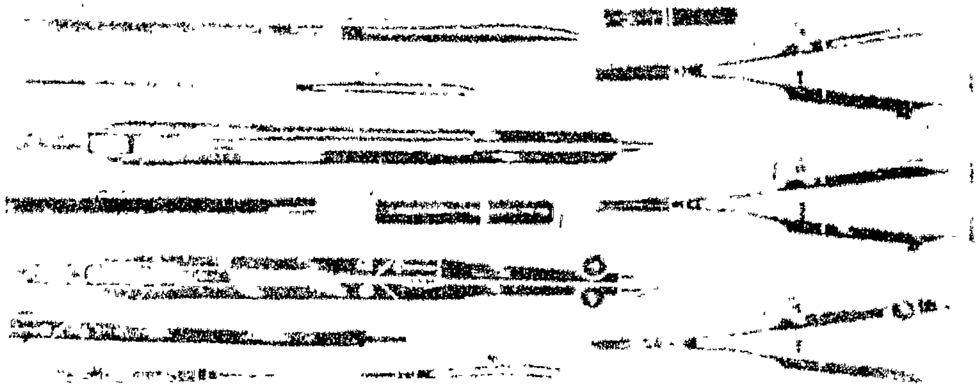


Fig. 2.8 A set of drawing instruments

of the radius is made possible by the screw arrangement.

The ruling pen is used for inking *straight* or *curved lines*. The ink should be carefully filled in between the blades of the nib by means of an ordinary pen. The thickness of the lines can be varied by the adjusting screw. The ruling pen should always be guided by a straight edge or French curve. The pen should be held in a plane perpendicular to the drawing surface, but inclined slightly to the direction of movement.

2.13 French Curves (Irregular Curves)

Curves, which are not circular, are best drawn with the help of French curves Fig. 2.9. These are also known as *irregular curves*. These curves are made of transparent plastic and are available in different forms and sizes. The edge of the French curve is lined up, by the trial-and-error method, so that it passes through at least three points of the required curve. It is important to see that the curve drawn is smooth without overlapping patches or sudden changes in direction.

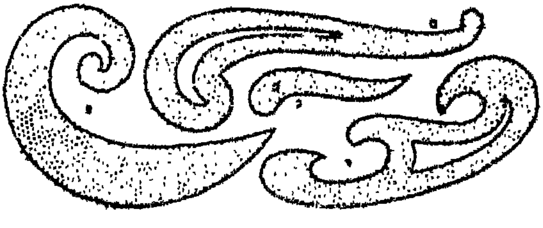


Fig. 2.9 French curve

2.14 Erasers

The eraser is used for removing (erasing) pencil or ink lines. Erasers are available in different grades of hardness. These are made of rubber. For erasing a pencil line, it should be rubbed repeatedly with a medium-soft eraser using only *light* pressure. Excessive pressure will damage the paper. Ink lines may be erased with a harder variety of eraser or may be scraped off with a razor blade. A very soft eraser known as *artgum* may be used for general cleaning of a drawing.

2.15 Erasing Shield

An erasing shield is used to protect the adjacent lines on the drawing when some part of a line is being erased. It is usually made of thin sheet metal. It has a number of holes of different shapes, Fig. 2.10.

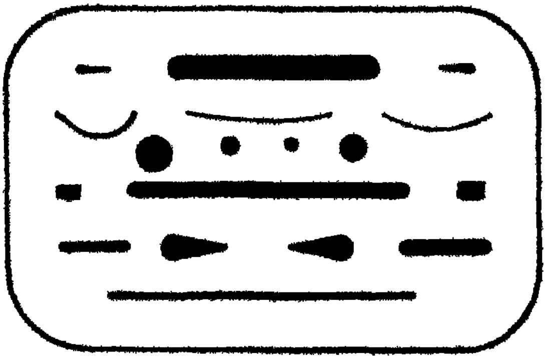


Fig. 2.10 Erasing shield

2.16 Indian Ink

The black drawing ink is known as the *Indian ink*. In some parts of the world it is also referred to as the *Chinese ink*. It is a colloidal solution of fine particles of carbon and gum. The bottle of ink should be carefully covered to prevent evaporation of the solvent. The bottle should never be left on the drawing which is being inked.

2.17 Lettering Pens

Lettering pens may be of the ordinary type consisting of a pen staff and a nib. These are used for freehand lettering. It will be found convenient to have a set of nibs which can be used for drawing lines of different degrees of thickness.

PROBLEMS

1. Give a list of essential drawing materials (instruments and equipment) required for your drawing-class work.
2. Why is it necessary to keep each piece of instrument or equipment in a definite place ?
3. What are the qualities of 7B and 9H pencils ?
4. What are French curves and how are they used ?
5. Demonstrate the use of your drawing instruments in drawing a square, a circle and a parallelogram of any convenient dimensions.

CHAPTER 3

Lettering, Lines, Scales and Dimensioning

3.1 Lettering—Main Requirements

Lettering is an important part of drawing. A complete drawing, in the first place, describes graphically the form of the object drawn. It further shows, by figured dimensions, the size of the object. Lastly, it describes by written specifications, the material to be used in its construction, the finish of the surfaces, the methods of construction and such other necessary information. Lettering, when neatly done, contributes much to the appearance of a drawing.

The lettering used on engineering drawings should be legible, uniform in appearance, simple and easy for rapid writing.

Either the vertical or the sloping types of letters and numerals may be used. The two types must not be mixed up. All letters should be in capitals, except where lower case (small) letters are accepted as standard abbreviations. The inclination of the sloping letters may be *approximately* 75 degrees to the horizontal.

The size of letters and numerals is specified by their heights. Recommended specimens of letters and numerals and their proportions, are shown in Fig. 3-1. Slightly varying alternative forms or styles of letters are also permissible provided they are

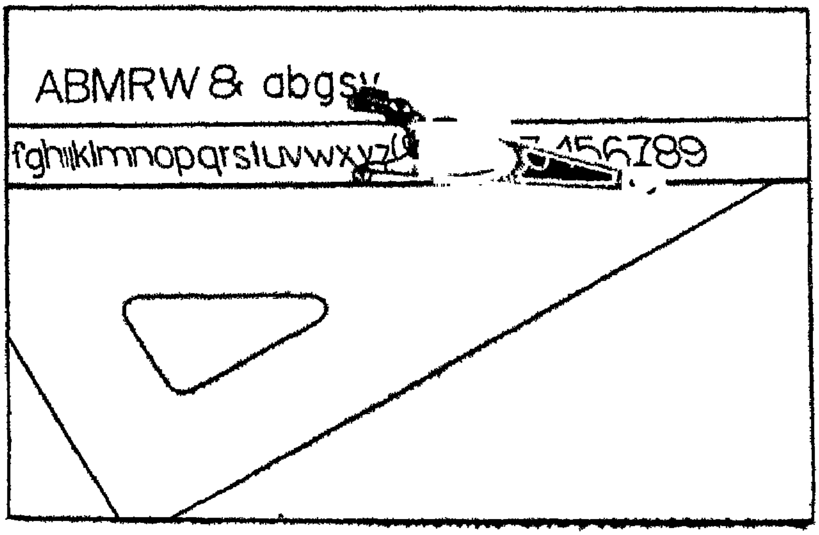


Fig. 3.0 Mechanical lettering device

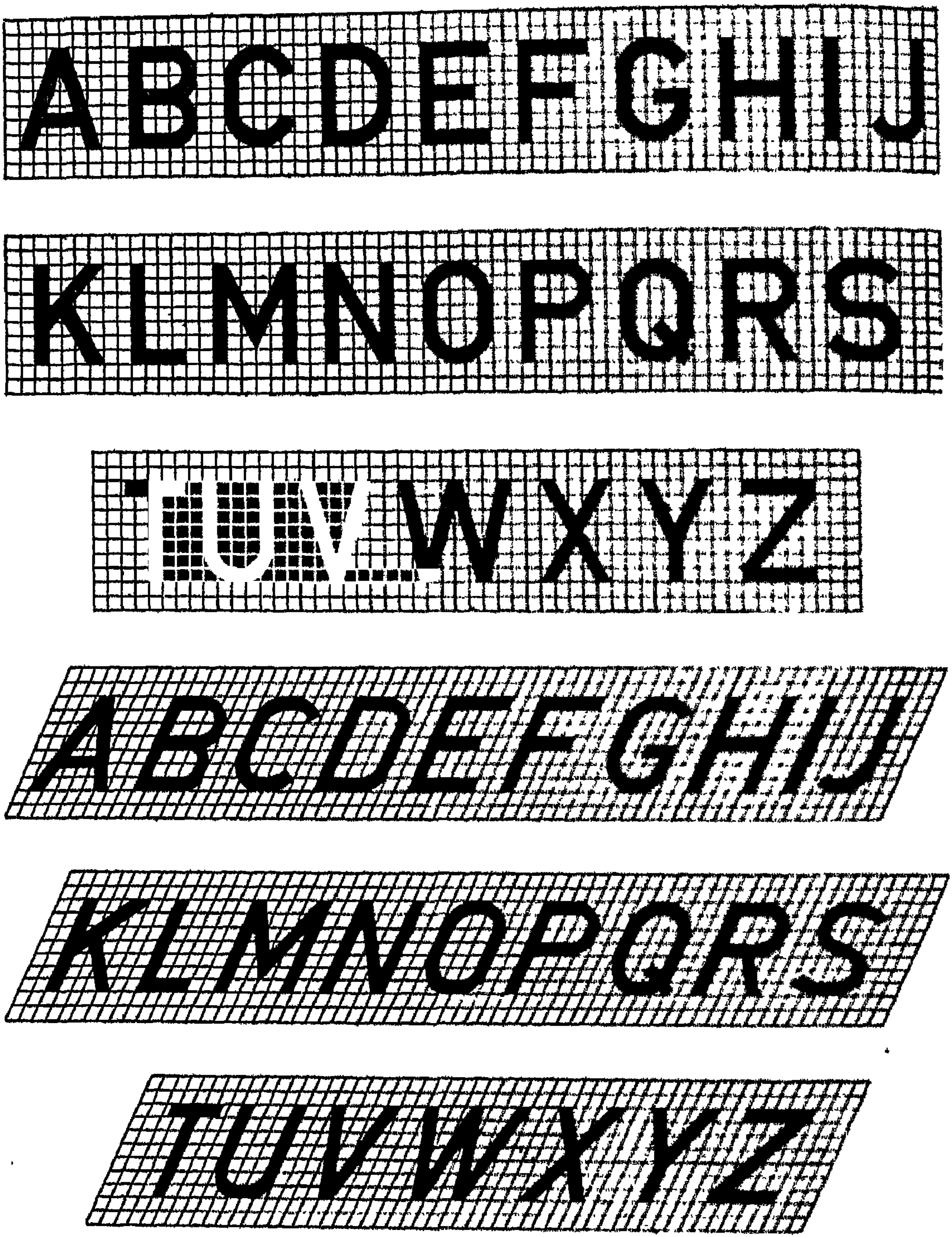
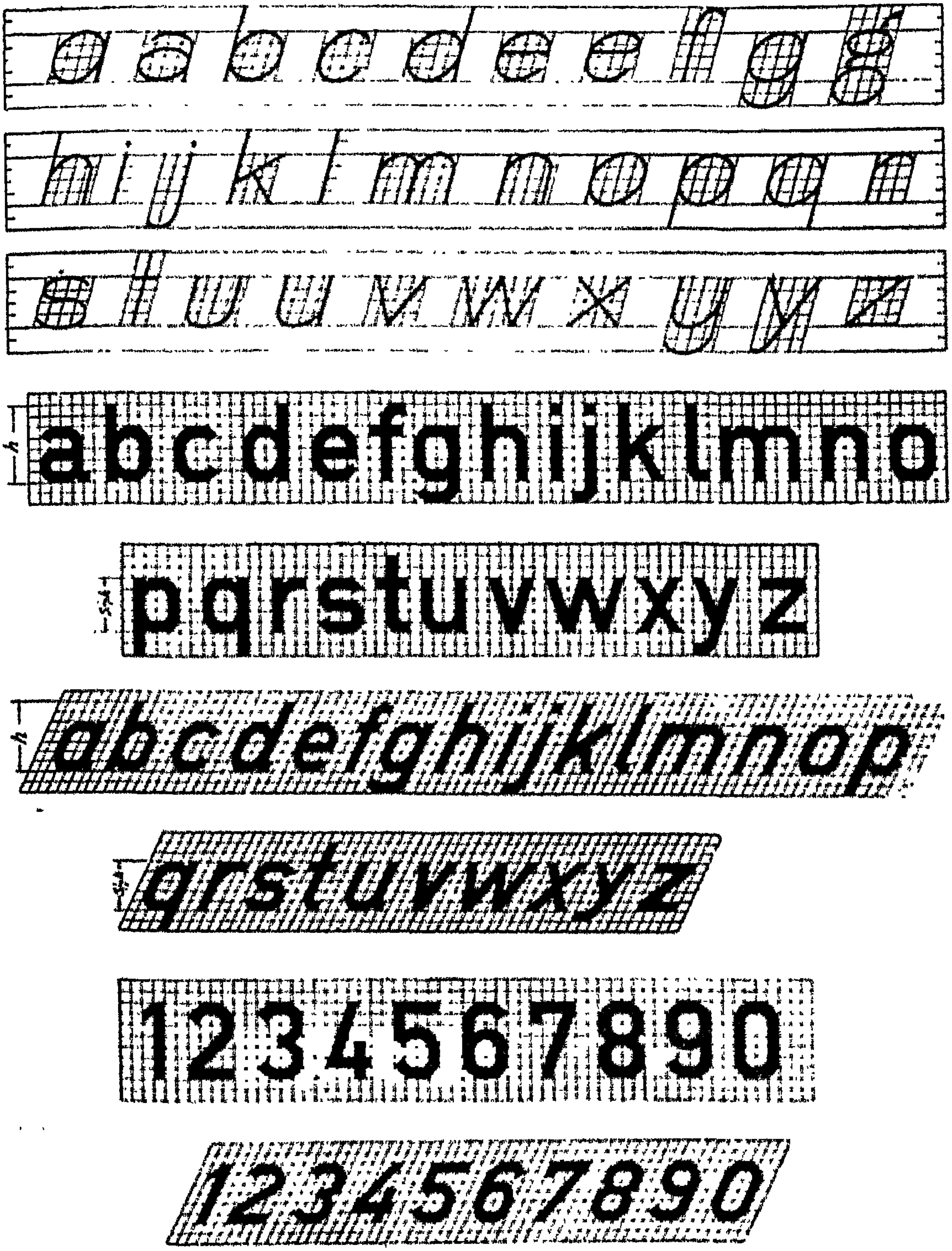


Fig. 3.1 Recommended specimens of letters and numerals



Recommended specimens of letters and numerals *(Contd.)*

easily recognizable and not unusual in appearance.

All letters and numerals should be kept clear of other lines on the drawing. Lettering should be done so that it may be read easily when the drawing is viewed from the bottom edge or from bottom and right-hand edges. The space between letters in a word should appear to be approximately equal.

3.2 Styles of Free-hand Lettering

There are many styles of lettering ; some of them are shown in Figs. 3.2 to 3.7.

The single-stroke Gothic style, Fig. 3.2, is the one mostly used in technical drawing because it is simple, legible and easy to make. Draughtsmen must master it by careful practice. All the lines (strokes) of the letters are of uniform thickness in the Gothic style.

The Old Roman style, Fig. 3.3, is the basis of all letters and is regarded as the most beautiful of all. The variation in thickness of lines is generally produced by pens with broad pointed nibs. This style or a modified version of it as shown in Fig. 3.4 is used in architectural drawing. Individual variations are permissible, if the lettering is well done and easily recognizable.

The Modern Roman style, Fig. 3.5, was evolved in the eighteenth century by the type founders. The letters in most of the printed books and newspapers are of this style.

The Old English style, Fig. 3.6, is used for decorative effect. It may be noted that there was no difference between I and J until the sixteenth century.

The All-straight-line style, Fig. 3.7, has no curved letters and is used for modern effect or special display.

All slanting letters are generally classified as *Italics* and are used for special emphasis or distinction.

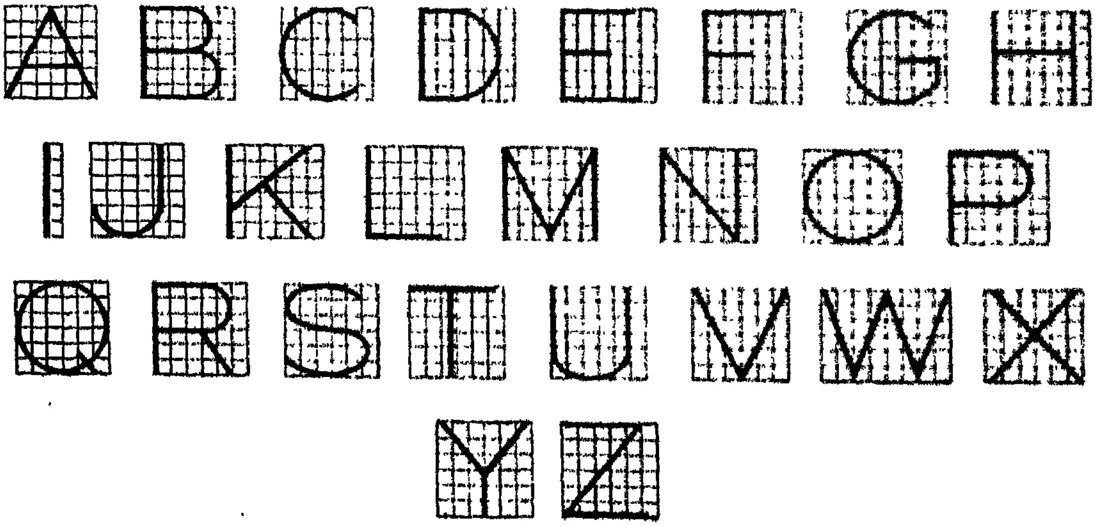


Fig. 3.2 The single-stroke Gothic style of letters

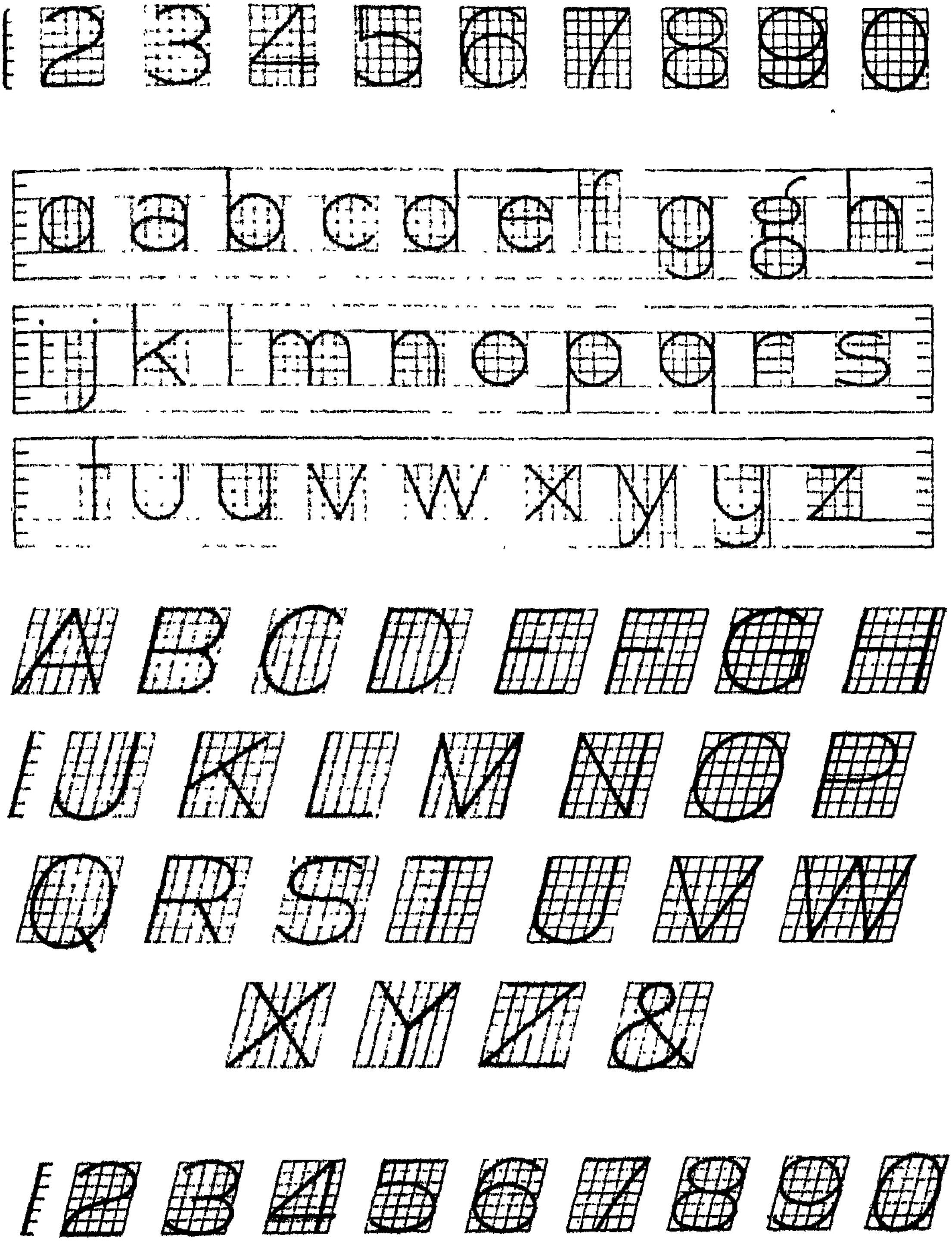


Fig. 3.2 The single-stroke Gothic style of letters

ABCDEFG
HIJKLMN
OPQRST
UVWXYZ
abcdefghijklm
nopqrstuvwxyz
1234567890

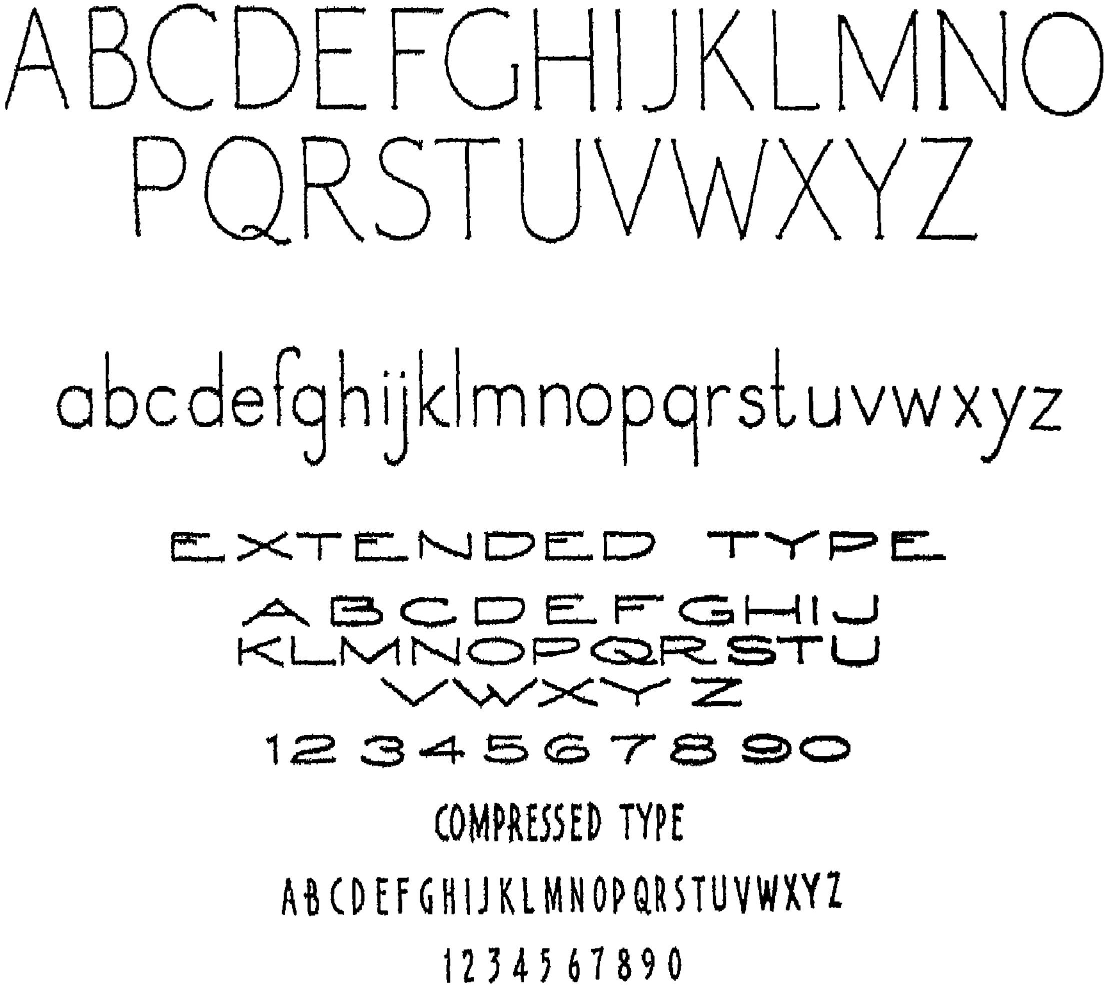


Fig. 3.4 Architectural style of letters

ABCDEF
GHIJKL
MNOPQR
STUVWX
YZ&

abcdefghijklm
nopqrstuvw
xyz

1234567890

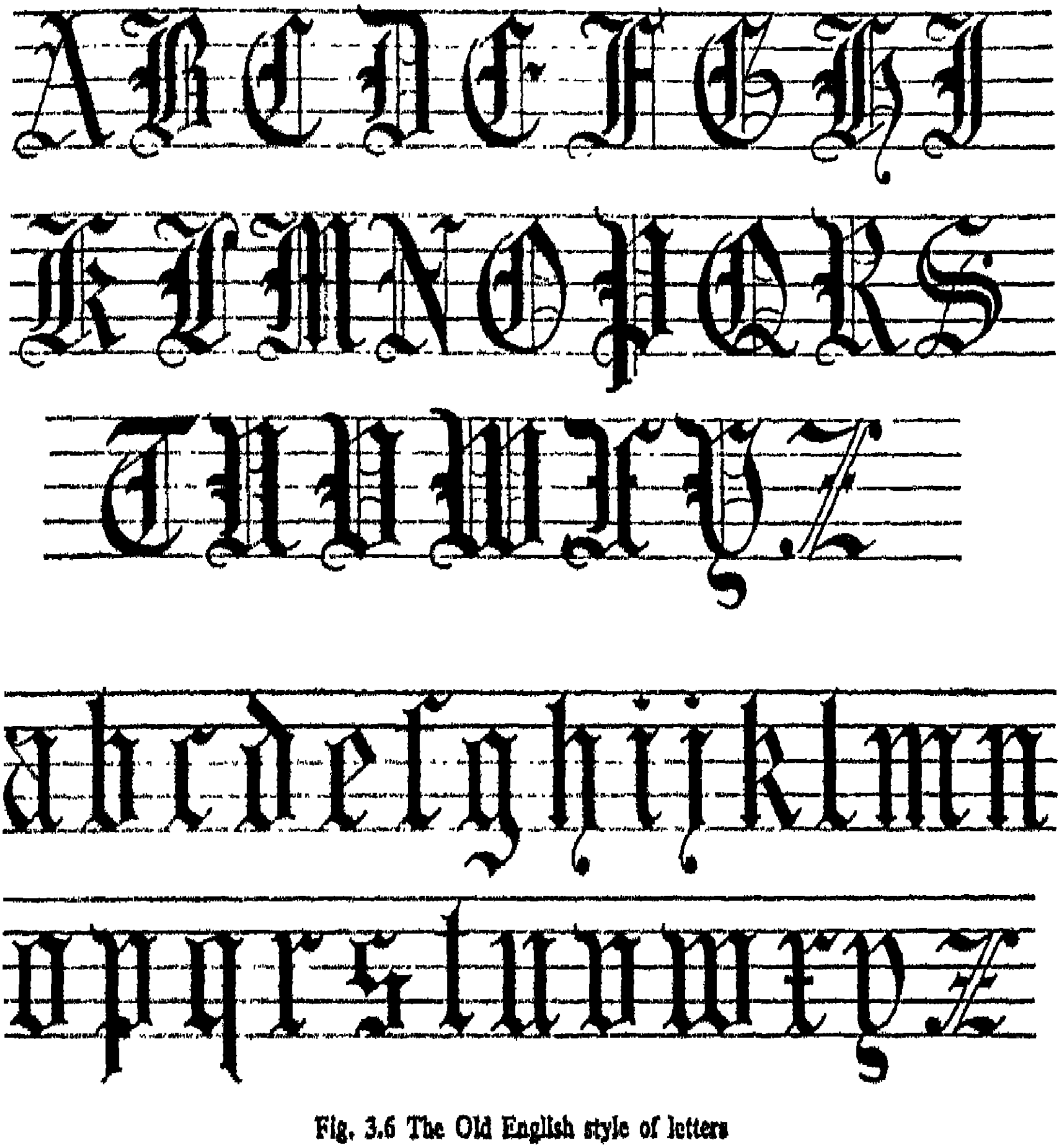


Fig. 3.6 The Old English style of letters

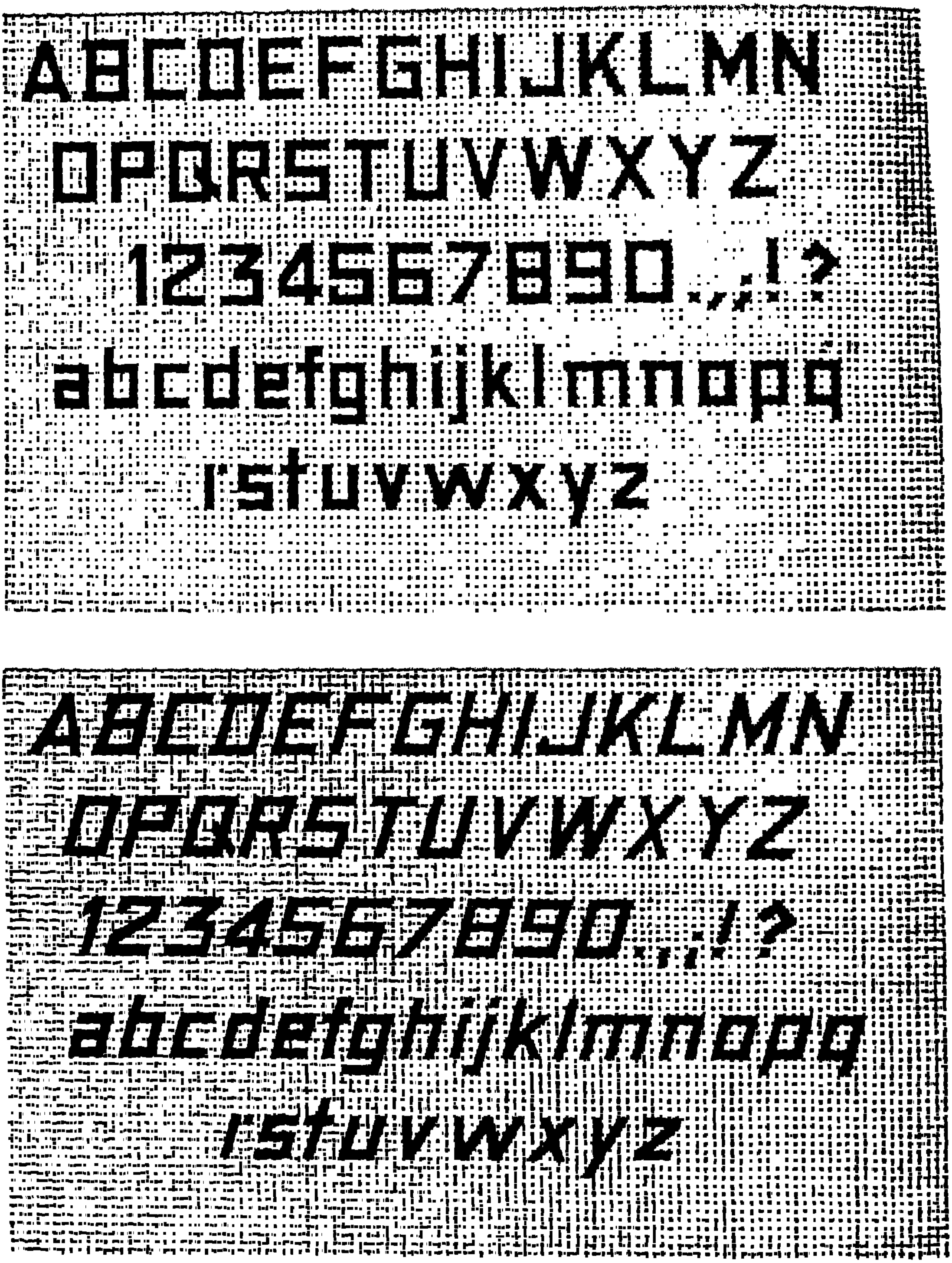


Fig. 3.7 The all-straight-line style of letters

3.3 Mechanical Lettering Devices

The Leroy Lettering Instrument is perhaps the best of its kind. A pin of the pen-holder follows grooved letters in a template (stencil) and the inking point (pen) moves on the paper. By adjusting the arm on the pen-holder the letters may be made vertical or inclined, Fig. 3.0.

3.4 Types of Lines and Their Uses

The types of lines are shown in Fig. 3.8a to j. All lines should be dense, uniform, clean and black to produce good prints. The outline of an object should be outstanding (prominent) on the drawing. Thick lines are relatively three times as thick and medium lines twice as thick as those specified as thin. Thickness of lines depend on the size and accuracy of the drawing. The thinnest line that a draughtsman can make is about 0.2 mm in thickness. This line will break down if reduced to half its thickness in reproduction.

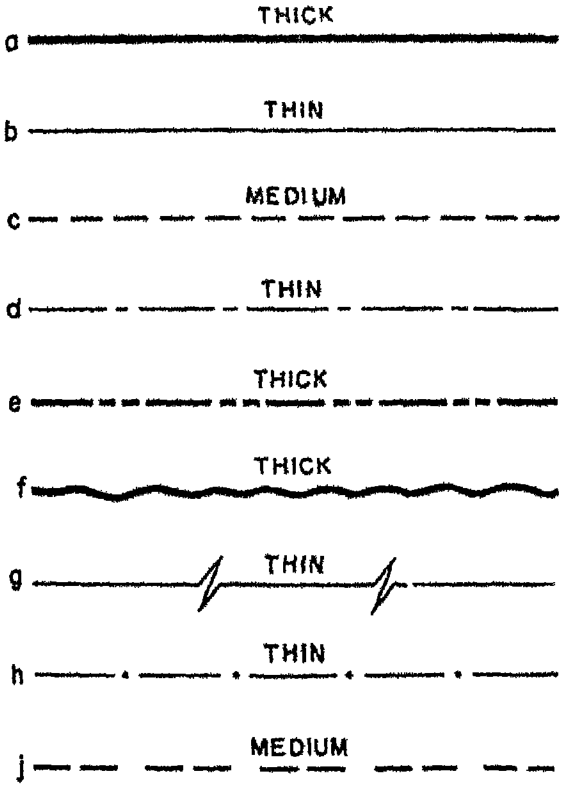


Fig. 3.8 Types of lines (IS: 696-1960)

Thick Full (unbroken) Lines (Type a, Fig. 3.8)—These are used to show the outline of objects. The outlines should be outstanding in the drawing.

Thin Full Lines (Type, b,m Fig. 3.8)—Thin full lines are used for dimension, extension, construction and hatching lines. Section lines should be spaced evenly to make a shaded effect. Dimension and extension lines should be thin full lines. They can thus contrast with the thicker outlines of the drawing, and should be placed outside the figure, wherever possible. The dimension line may be broken in the middle for inserting the dimension.

Broken Medium Lines (Type c, Fig. 3.8)—These consist of short dashes, closely and evenly spaced. These are used to indicate hidden lines of objects on the drawing.

Centre Lines (Type d, Fig. 3.8)—Centre lines should project for a short distance beyond the outline of the object. Centre lines may be extended if necessary for dimensioning or to correlate views. Alternate long and short dashes should have a proportion ranging from 6 :1 to 4 :1 closely and evenly spaced. The ratio once adopted should be maintained in every single drawing. These are also used to denote locus lines, Fig. 3.9.

Cutting Plane Lines (Type e, Fig. 3.8)—Cutting plane lines are formed by a thick long dash and two short dashes alternately and evenly spaced, and lettered as shown in Fig. 3.10. The arrow heads at the ends indicate the direction of viewing.

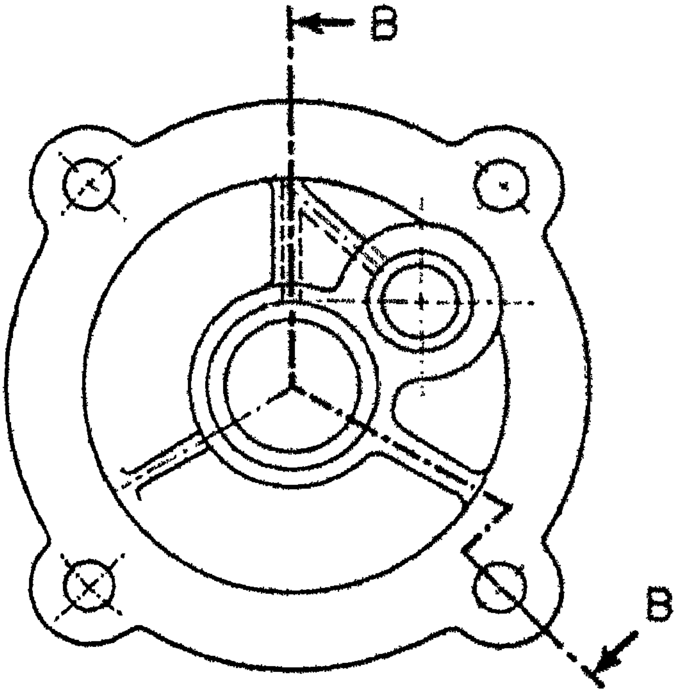


Fig. 3.10 Line indicating cutting plane (IS: 696-1960)

Break Lines (*Types f and g, Fig. 3.8*)—These are used to show breaks in the views of the objects, for convenience in representing very long or large parts on drawing. For small parts thick freehand irregular lines (type f) are used. For assemblies or large parts, thin ruled lines with freehand zigzags (type g) are preferred. For conventional breaks see Fig. 3.11.

Lines Indicating Alternate Positions (*also called Phantom Lines*), *Adjacent Parts, Overhead Lines* (*Telegraph or Electric Transmission Lines*) (*Type h, Fig. 3.8*)—These are made up of long dashes and dots put down alternately (See Figs. 3.9 and 3.12).

Ditto Lines (*Types j, Fig. 3.8*)—Ditto lines are used to show repeated details. These are short double dashes evenly spaced out.

3.5 Scales

The drawing of a house, bridge or a large machine cannot certainly be as large as the object itself. It is necessary, therefore, to draw them to a reduced scale for convenience. To understand the details of a wrist-watch mechanism, it is necessary to make the drawing of those tiny parts to an enlarged scale. It is therefore necessary to choose suitable scales in order to make the drawings of the objects under consideration.

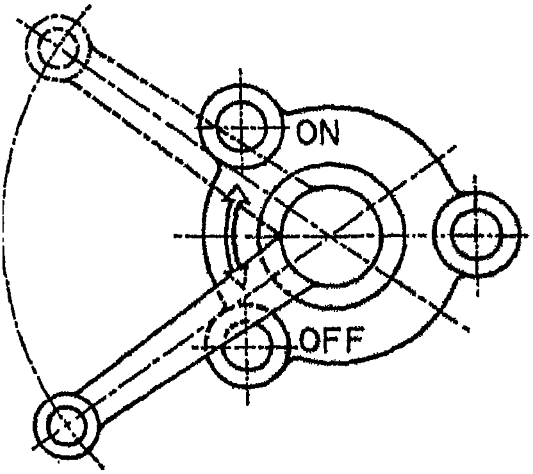


Fig. 3.9 Indication of alternate position (IS: 696-1960)

The scales adopted for drawings will depend on the degree or accuracy required of scaled distances on the drawing. In general, the largest scale possible should be used. Scaled distance may be read only to an accuracy of 0.5 mm. This represents an accuracy of 50 mm. in drawings to a scale of 1:100. The scale of the drawing will decide the size of the sheet to be used. However, all dimensions must be explicitly shown on the drawings. Scaling (measuring) distances on drawings for determining

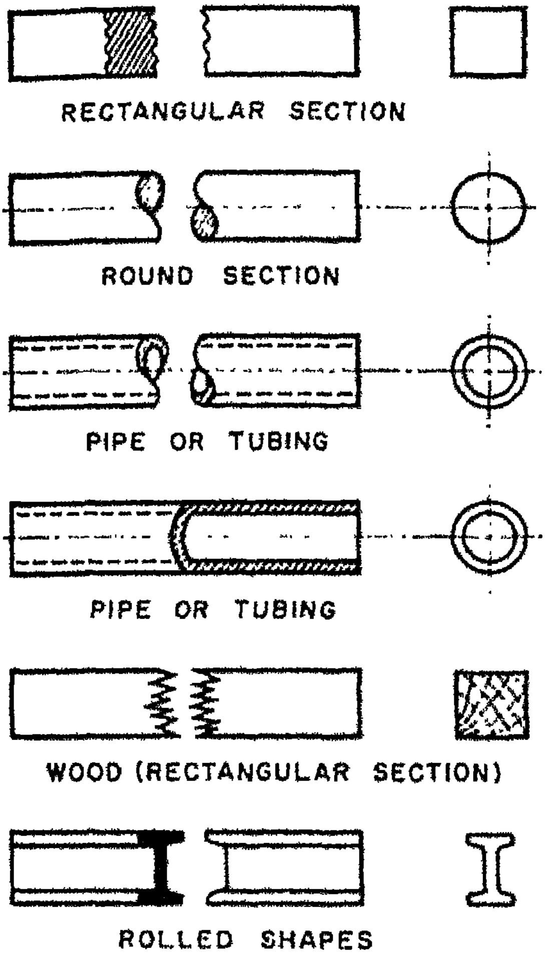


Fig. 3.11 Conventional breaks (IS: 696-1960)

dimensions should be avoided as a rule.

Indication of Scales on Drawings—The scale of the drawing should be indicated in the appropriate place in the title block. If different parts are drawn to different scales on one sheet, the corresponding scale should be shown under each relevant detail, by a numerical ratio thus :

Scale 1 : 1 (full size)

Scale 1 : 50 (reducing scale, i.e., one unit on the drawing represents 50 units of the object)

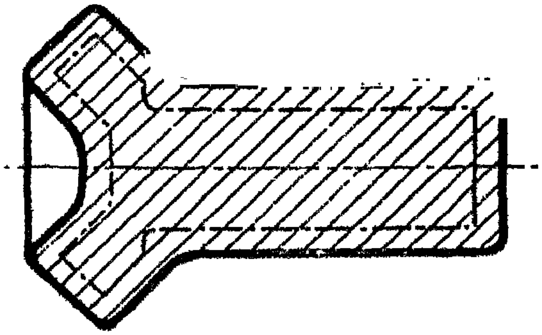


Fig. 3.12 Showing machining allowance (IS: 696-1960)

Scale 10 : 1 (enlarging scale, i.e., 10 units on the drawing represent one unit of the object).

In other words, the scale indicates the representative fraction or the ratio of true length on the drawing to the true length of the object represented. The scales recommended are :

(*a*) *General Engineering Drawings :*
1:1, 1:2, 1:2.5, 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 10:1, 5:1, 2:1.

(*b*) *Architectural and Civil Engineering* :
1:1, 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:1000, 1: 2000.

(*c*) *Geographical Maps:*
ranges from 1:500 000 to 1:16 000 000.

Graphic Scales—Drawings or prints may shrink or enlarge due to the variation of humidity of the atmosphere. Hence, it is advisable to provide a graphic scale, such as Fig. 3.13 in addition to demoting the scale adopted by the numerical ratio, to effect the necessary enlargement or reduction of drawings. Sometimes, both vertical and horizontal graphic scales are drawn to take care of distortions in both directions of the drawing.

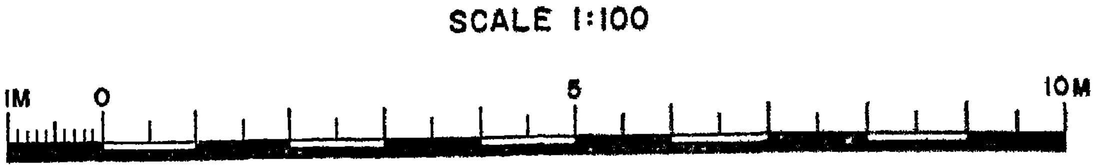


Fig. 3.13 Graphic scale (IS: 696-1960)

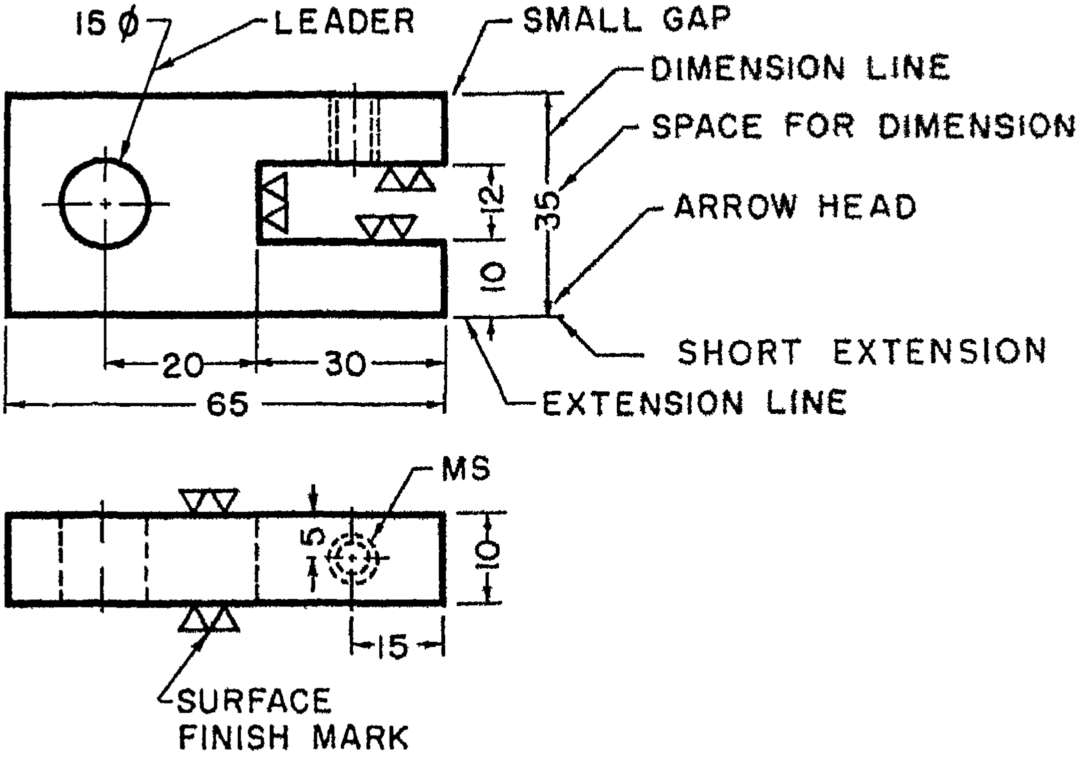


Fig. 3.14 Notation of dimensioning (IS: 696-1960)

3.6 Dimensioning

Dimensioning means indicating or expressing on the drowing all the dimensions (size measurements) and other information necessary to define the object completely in its finished form. Dimensioning must be done with due regard to manufacturing or construction processes and inspection requirements. Dimensioning includes expression of tolerances necessary for the correct functioning of the part.

Dimensioning on a drawing is done by using lines, symbols, figures and notes. Some of the terms used are explained below.

(1) *Dimension line* is a light full line used to indicate the measurement which is shown in figures (numerals) in a space left in the dimension line or above the dimension line.

(2) *Extension lines (projection lines)* are light full lines extending beyond the

outline of the object. There should be a gap of about 2 mm. outside the outline of the object and the lines should extend about 3 mm. beyond the dimension line as in Fig. 3.14.

Projection lines are drawn in a direction perpendicular to the feature to be dimensioned (see Fig. 3.14), or where it is necessary, are drawn obliquely but preferably parallel to each other (see Fig. 3.15).

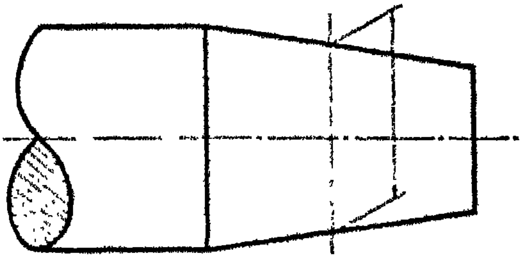


Fig. 3.15 Projection lines of tapered features (IS: 696-1960)

For clarity, the construction lines and the intersecting projection lines may be extended slightly beyond their point of intersection as shown in Fig. 3.16.

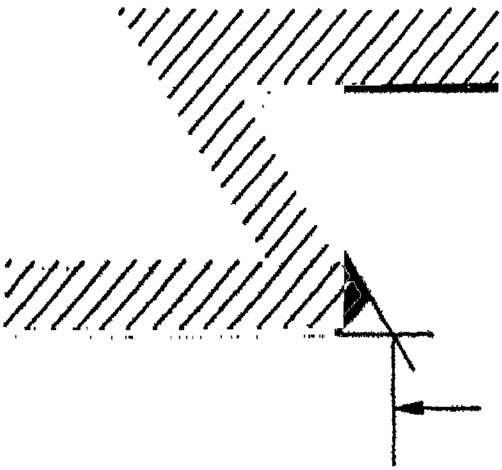


Fig. 3.16 Construction lines extended for dimensioning (IS: 696-1960)

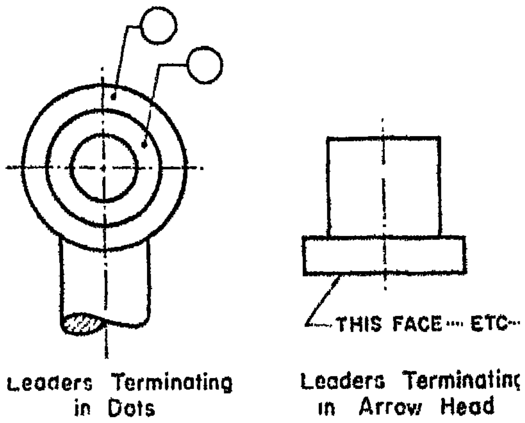

THIS FACE ···· ETC··
Leaders Terminating in Dots
Leaders Terminating in Arrow Head

Fig. 3.17 Typical leaders terminating in dots (IS: 696-1960)

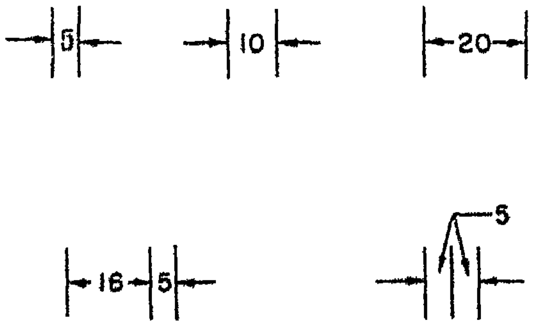


Fig. 3.18 Dimensioning narrow spaces (IS: 696-1960)

(3) *Leaders* (*pointer lines*) are lines *drawn* from notes and figures to show where these apply. These are thin straight lines terminated by arrowheads, or dots (see Fig. 3.17). These lines should not be curved or drawn free-hand. The leader may terminate in a short horizontal bar at the mid-height of the lettering at the beginning or end of the note (see Fig. 3.14).

The use of long leaders should be avoided even if it means repeating dimensions or notes.

(4) *Arrowheads* are used to terminate dimension lines. The length of the arrowhead is about three times its width. The space in the arrowhead should be filled in.

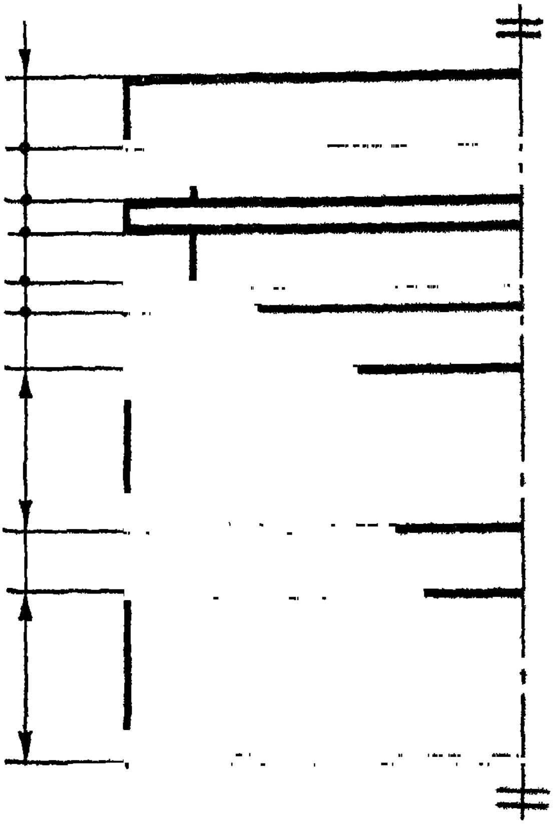


Fig. 3.19 Arrow heads replaced by clearly marked dots (IS: 696-1960)

Adjacent arrowheads may be replaced by clearly marked dots where space is limited, Figs. 3.17 and 3.19.

(5) *Systems of placing dimensions* :

The two recommended systems of placing dimensions are :

(*a*) Aligned system—In this system all dimensions are so placed that they may be read from the bottom or right hand edges of the drawing, Fig. 3.20. The dimensions are shown standing normal to the dimension line.

(*b*) Unidirectional system—In this system, all the dimensions are so placed that they may be read from the bottom of the sheet as shown in Fig. 3.21. In this method the dimensions are always written vertically irrespective of the directions of the dimension line. The unidirectional system is advantageous on large drawings.

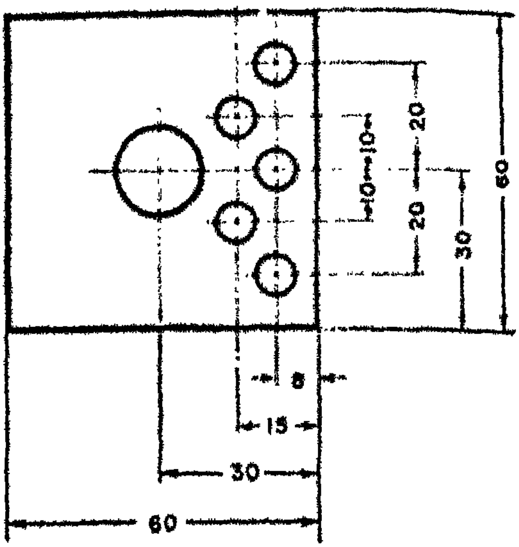


Fig. 3.20 Aligned dimensioning from centre line and finished surface (IS: 696-1960)

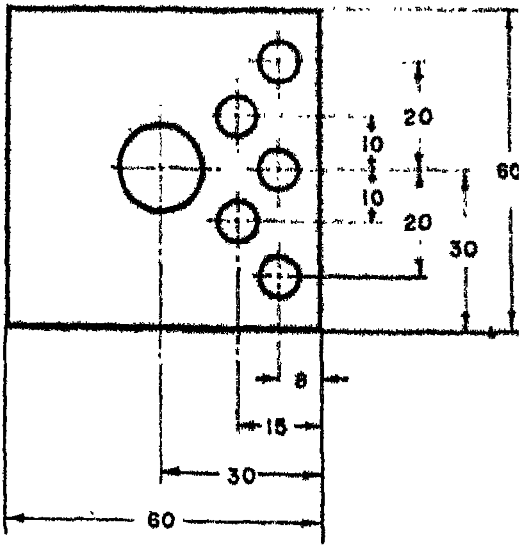


Fig. 3.21 Unidirectional dimensioning from centre line and finished surface (IS: 696-1960)

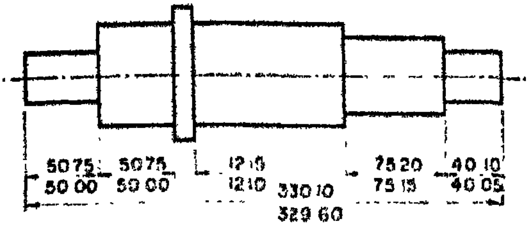


Fig. 3.22. Limiting dimension with one intermediate dimension omitted (IS: 696-1960)

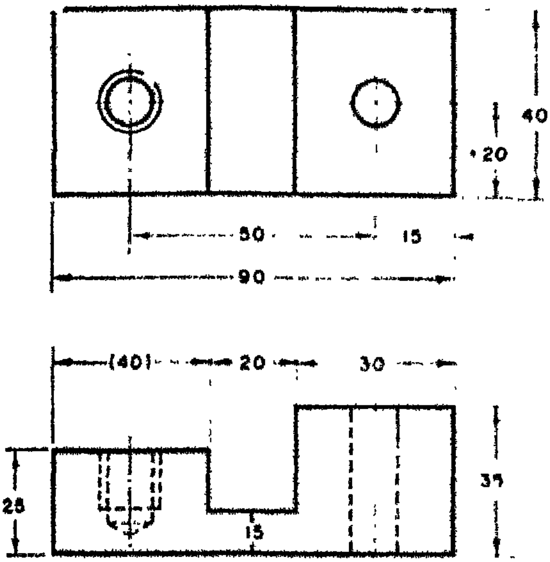


Fig. 3.23 Placing of dimensions (IS: 696-1960)

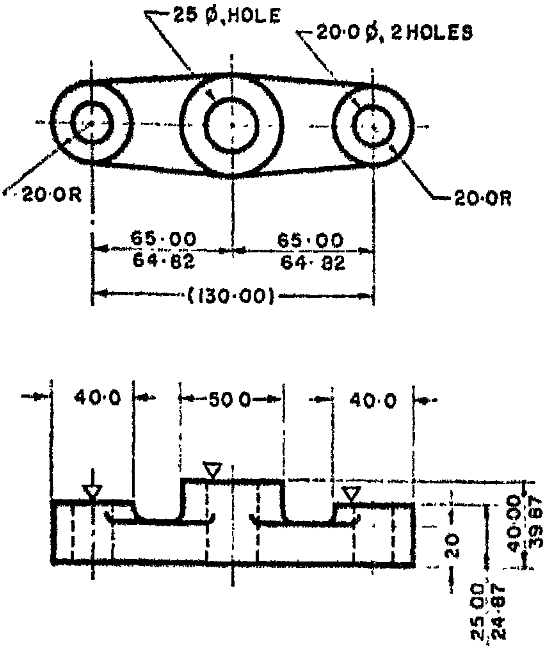
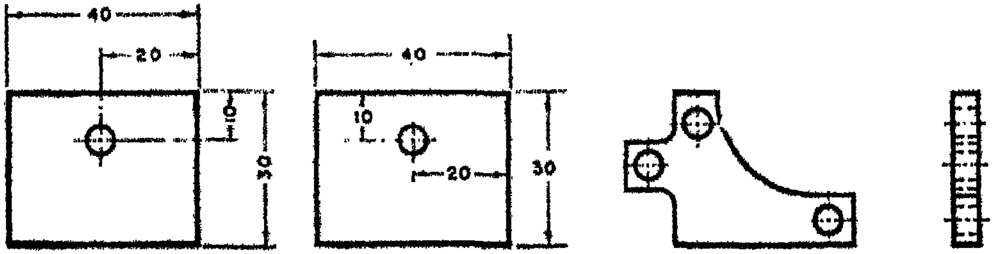


Fig. 3.24 Dimensioning parts with circular ends

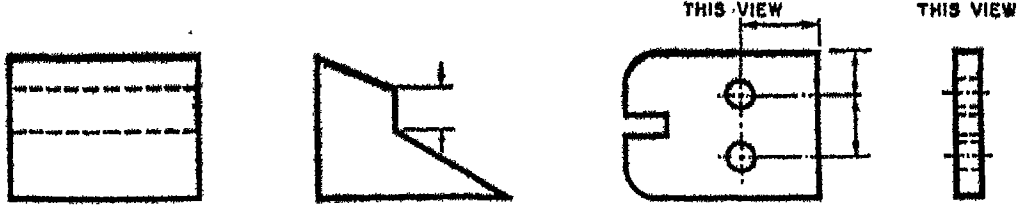


CORRECT

INCORRECT

SHOW CONTOURS AND HOLE DIMENSIONS IN THIS VIEW

SHOW THICKNESS DIMENSION IN THIS VIEW



DO NOT DIMENSION IN THIS VIEW

DIMENSION IN THIS VIEW

SHOW HOLE LOCATIONS IN THIS VIEW

DO NOT LOCATE HOLE IN THIS VIEW

Fig. 3.25 Dimension placed on the view best showing the effect of dimension (IS: 696-1960)

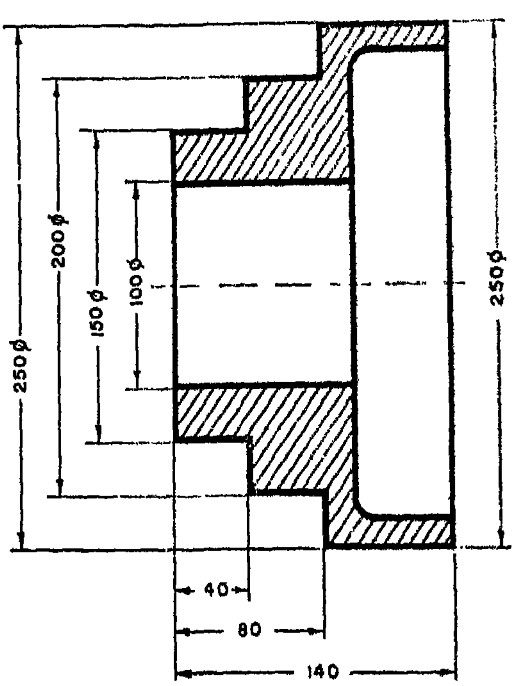


Fig. 3.26 Dimensioning cylindrical parts (IS: 696-1960)

Some general principles of dimensioning are as follows :

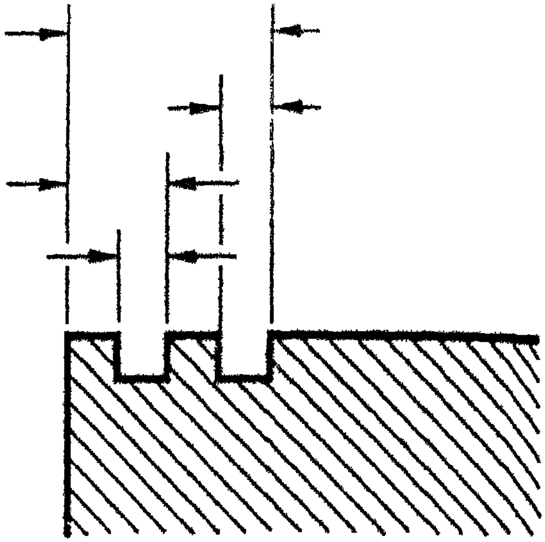
(1) All the dimensions and other information *necessary* to define the object completely must be shown directly on the drawing.

(2) More than necessary dimensions should not be shown on the drawing. When an overall dimension is used, one of the intermediate dimensions should be omitted (see Fig. 3.22).

(3) Dimensions should be stated once only ; and should not be repeated in different views except for reference purposes.

(4) Dimensions should be shown on the view which shows the relevant features most clearly.

(5) In general, dimensions should be placed (a) outside of views, where possible, and (b) between views, as shown in Figs. 3-23 and 3.24.



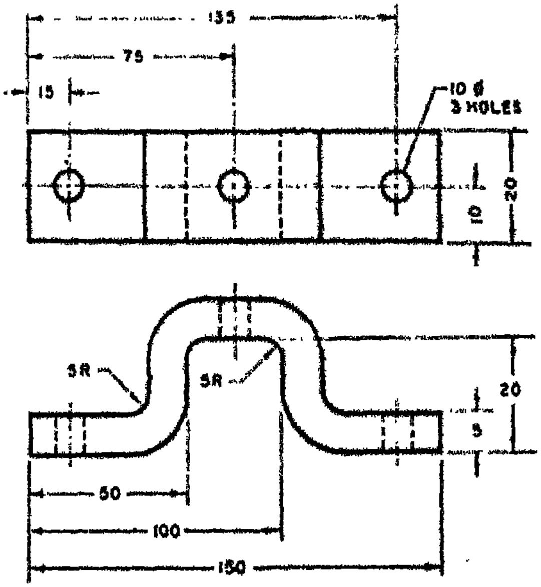


Fig. 3.27 Further examples in dimensioning (IS: 696-1960)

(6) Dimensions should not be placed too close to each other or to the part dimensioned.

(7) Dimensions should be shown against visible outlines and not against hidden lines (Fig. 3.25). Dimensions should be given from a base line, a centre line, an

important hole, or a finished surface which may be readily established, based on design requirements and the relationship with other parts (Figs. 3.20 and 3.21).

(8) The crossing of dimension lines should be avoided as far as possible. Dimension lines should be broken only to insert the dimension figures.

(9) The dimension line should not pass through a dimension figure, nor should a dimension figure be placed on the outline of the object.

(10) A centre line should never be used as a dimension line. Also, a line of the part illustrated, or an extension of such a line, should never be used as a dimension line.

(11) When there are several parallel dimension lines, the figures should be staggered to avoid confusion as shown in Fig. 3.26.

(12) For dimensioning in limited space, the arrowheads should be reversed as shown in Figs. 3.18 and 3.27. Adjacent arrowheads may be replaced by clearly marked dots, Fig. 3.19.

(13) Dimensioning should, as far as possible, be expressed in one unit only ; preferably, in millimetres. The symbol for the unit, mm., may then be omitted. But in that case, a prominent note should be added stating the unit in which all the dimensions of the drawing are expressed.

PROBLEMS

1. State the main requirements of lettering in engineering drawings.
2. Draw freehand, a complete set of small capital letters and numerals of the vertical (upright) type on a graph paper. The height of letters must be not less than 15 mm.
3. Draw freehand, a complete set of small (lower case) letters of the vertical type on a graph paper. The height of letters must be not less than 10 mm.
4. Draw freehand, a complete set of small letters and numerals of the inclined type on a graph paper. The height of the letters must not be less than 10 mm.
5. Draw freehand, a complete set of capital letters of the inclined type on a graph paper. The height of the letters must not be less than 15 mm.
6. Name a few styles of lettering and state which one is most commonly used in technical drawings.
7. Draw a set of different types of lines used in engineering drawings.

8. What are reducing or enlarging scales ?

9. What does a scale 1 : 20 indicate ?

10. What is the meaning of the words "scale 10 : 1" ?

11. When do you use graphic scales ?

12. What are (i) dimension lines, (ii) extension lines, (iii) projection lines, (iv) leaders ?

13. What is dimensioning ?

14. Sketch an arrow head and indicate its proportions.

15. What are (i) aligned system and (ii) unidirectional system of dimensions ?

16. Make neat drawings of Figs. 3.14 to 3.27 to an enlarged scale 2: 1, and clearly state the significance of each figure.

CHAPTER 4

Geometrical Constructions

4.1 Introduction

Geometrical constructions deal with problems in practical geometry. The solutions of these problems are based on the theoretical principles of geometry. Geometrical construction problems are frequently met with both in the workshop and in the drafting room. A student of pure geometry is restricted to use only ruler and compass. But an engineer is free to use all the instruments available to him so long as the desired accuracy is achieved. Accuracy in geometrical constructions is achieved by careful use of the instruments and by drawing lines with sharp pencil points.

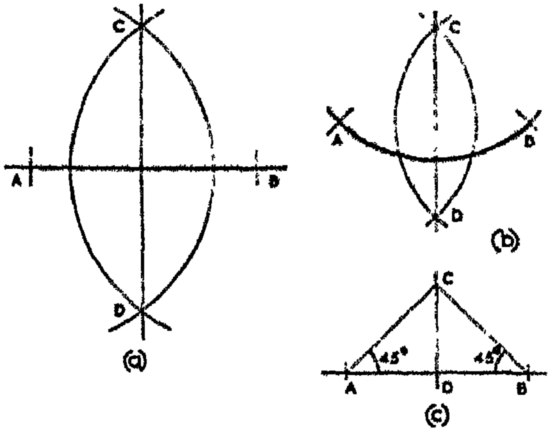


Fig. 4.1 Bisecting a line

4.2 To Bisect a Given Line AB

Method (*i*). With any radius greater than one-half AB describe two arcs with A and B as centres, Fig. 4.1a. The line CD, joining the points of intersection of the arcs, is the perpendicular bisector of the given line.

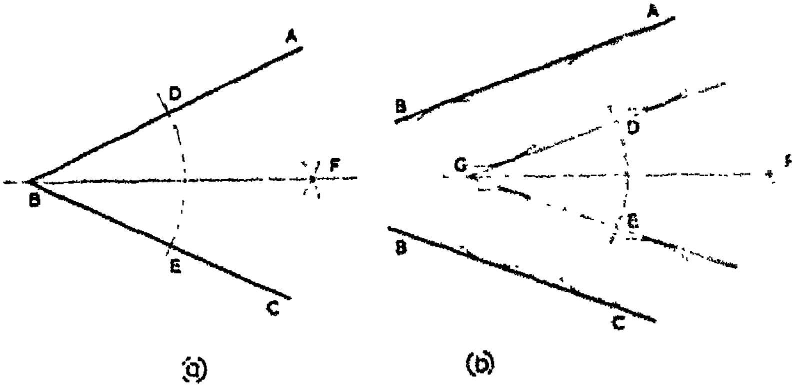
The arc of a circle, AB may be bisected in a similar manner, Fig. 4.1b.

Method (*ii*). Using set-square and T-square draw lines inclined at 45° through A and B as shown in Fig. 4.1c. Through their points of intersection draw CD the perpendicular bisector to AB. No compass is used in this method.

4.3 To Bisect A Given Angle ABC

Case (a). Vertex B is accessible, Fig. 4-2a. With B as centre, and a large radius describe an arc intersecting BA and BC at D and E respectively. With D and E as centres, describe arcs of equal radii intersecting at F. BF is the required bisector.

Case (b). Vertex is inaccessible, Fig. 4-2(b). Draw lines DG and EG parallel to the given lines, and at equal distances from them, so as to intersect at G. Bisect the angle DGE as in case (a) by GF, the required bisector.



(a) (b)

Fig. 4.2 Bisecting an angle

4.4 To Divide a Straight Line AB into a Given Number of Equal Parts

Let the number of equal parts be five, Fig. 4.3. Draw the line AC at any convenient angle with AB, and mark off, with dividers or scale, five equal lengths from A to D. Join D to B and draw parallels to DB through the other points in AD. The intersections of these parallels with AB give the required equal parts.

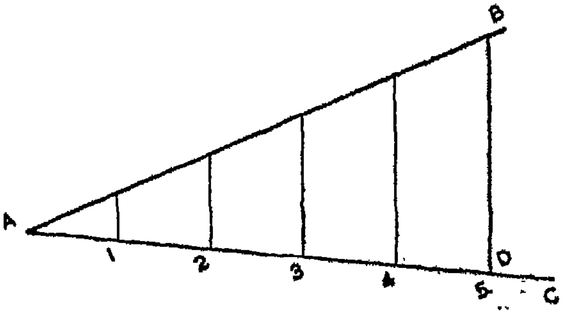
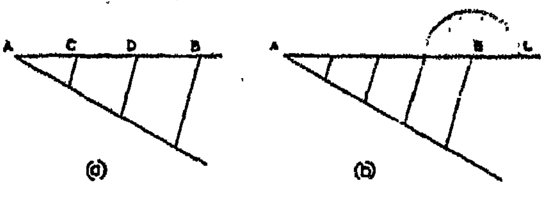


Fig. 4.3 Dividing a straight line into required number of equal parts



(a) (b)

Fig. 4.4 Reducing or enlarging linear dimensions

4.5 To Reduce or Enlarge Linear Dimensions

Case (a). Let AB be the given dimension, Fig. 4.4a. It is required to reduce it, say, to 2/3 of its length. Divide the length AB into three parts as in problem 4.4 above. BC or AD is the required reduced length.

Case (b). Let AB be the given dimension, Fig. 4.4b. It is required to enlarge it, say, to 5/4 times its length. Divide the length AB into four parts as above and mark off a length BC on AB produced equal to one-fourth part of AB. AC is the enlarged length required.

4.6 To Draw Tangents to Circles

(i) *To draw a tangent to a circle at a given point P on the circumference, Fig. 4.5.* Draw the radius line OP through O the centre of the circle. Using set-squares draw a line PT perpendicular to OP.

(ii) *To draw a tangent to a circle through a given point outside the circle.* Let O be the centre of the given circle and P the external point, Fig. 4.6. Join PO; bisect PO and draw a semicircle cutting the given circle in T. Draw PT, the required tangent.

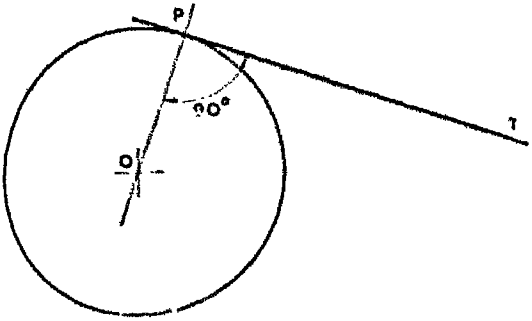


Fig. 4.5 Tangent through a given point on the circle

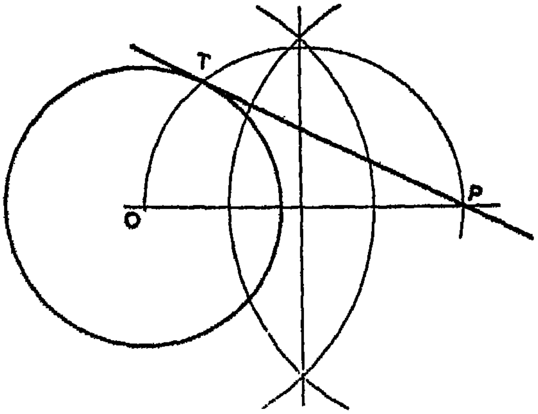


Fig. 4.6 Tangent through a point outside the circle

(iii) *To draw a tangent through a point P on a circular arc having an inaccessible centre.* Draw the chord PA, Fig. 4.7; draw a perpendicular bisector to PA. With P as centre draw an arc through the point B where the perpendicular bisector cuts the given arc. With B as centre and radius equal to BC, the chord distance, draw a circle. From P draw PT the required tangent which touches the arc and also the circle with radius BC.

(iv) *To draw common tangents to two given unequal circles.* Given circles have centres O and O′ and corresponding radii r and r′ $(r>r')$.

Case (a). Common internal tangents, Fig. 4.8(a). Draw a circle having the same centre O as the larger circle and a radius equal to the sum of the radii $(r+r')$; construct a tangent O′A from centre O′ of the smaller circle to this circle. Construct O′B perpendicular to this tangent O′A. Draw OA. The line BC joining the extremities of the radii OC and O′B, is a common tangent. Another common tangent B′C′ can be similarly constructed.

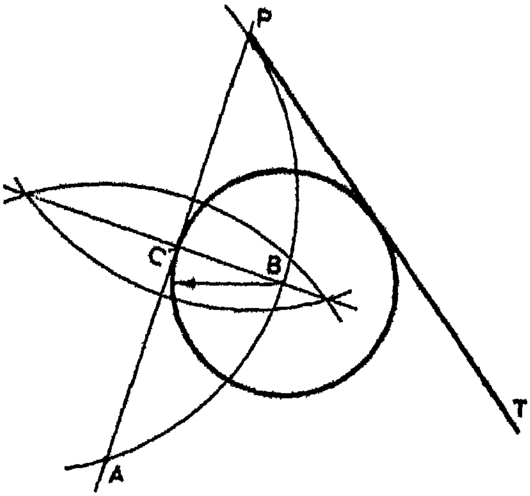


Fig. 4.7 Tangent through a point on an arc with inaccessible centre

Case (b). Common external tangents, Fig. 4.8 (b). Draw a circle having the same centre O as the larger circle and radius equal to the difference of the radii $(r-r')$.

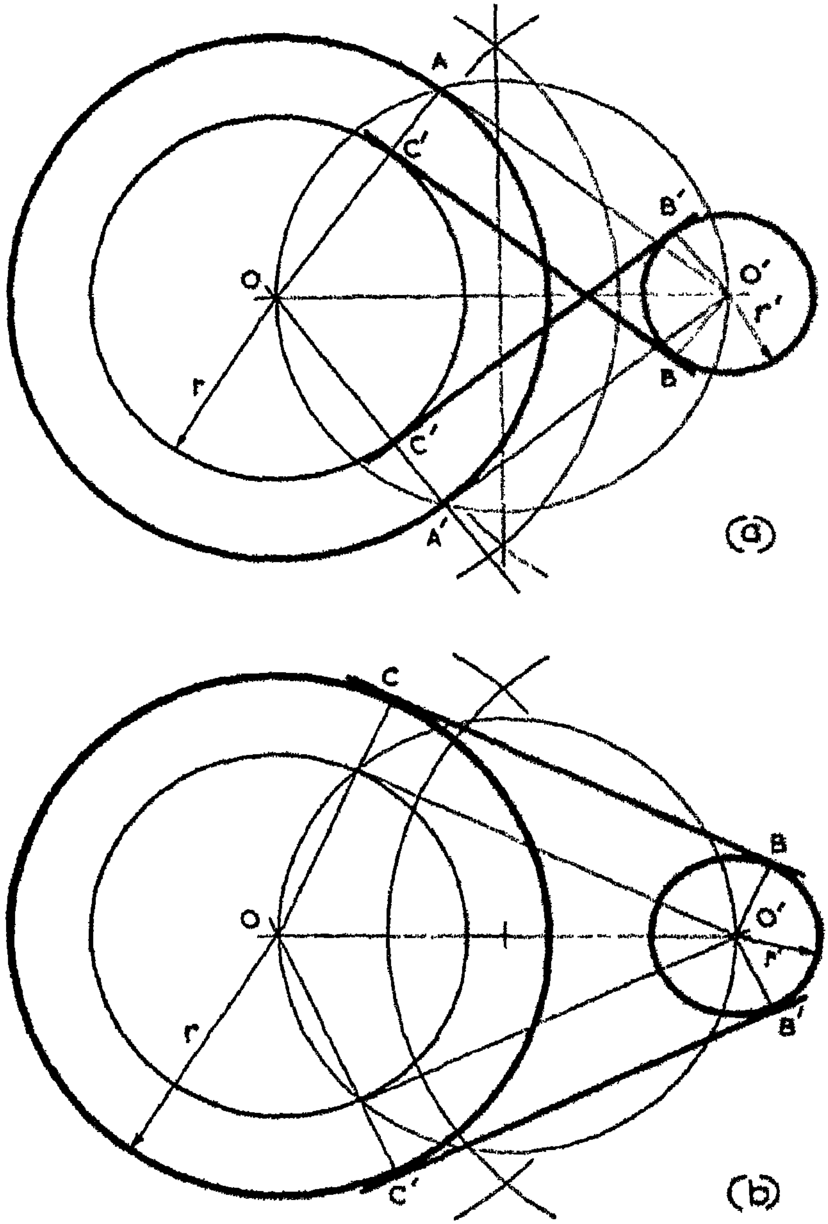


Fig. 4.8 Common tangents to two circles

Construct a tangent to this circle from the centre of the smaller circle ; draw radii OC and OB perpendicular to this tangent. BC is the required common tangent. Another common tangent B'C' can be similarly constructed.

4.7 To Construct Circles in Rectilinear Figures

(*i*) *To construct a circle passing through*

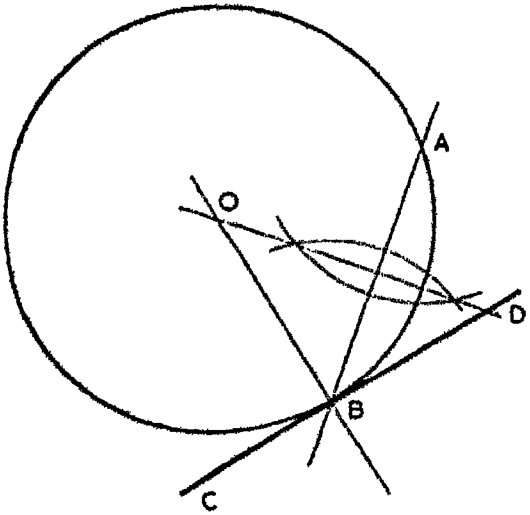


Fig. 4.9 Circle through a given point touching a straight line at a given point

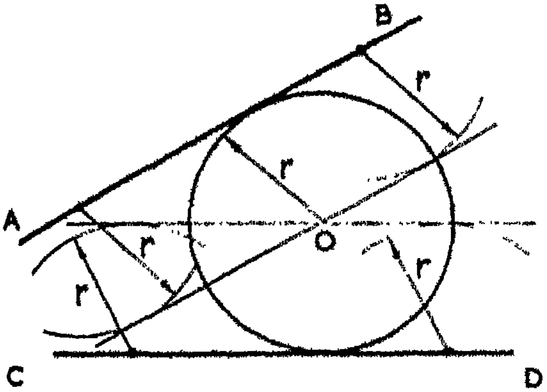


Fig. 4.10 Circle touching two converging lines

a given point A and touching a given straight line CD at a given point B, Fig. 4.9. At B draw BO perpendicular to the given line. Join AB ; and construct the perpendicular bisector of AB to intersect BO at O the centre of the required circle. With O as centre and radius OB describe the circle.

(*ii*) *To construct a circle of a given radius r to touch two converging lines AB and CD, Fig. 4.10.* Draw lines parallel to AB and CD at distances equal to r.

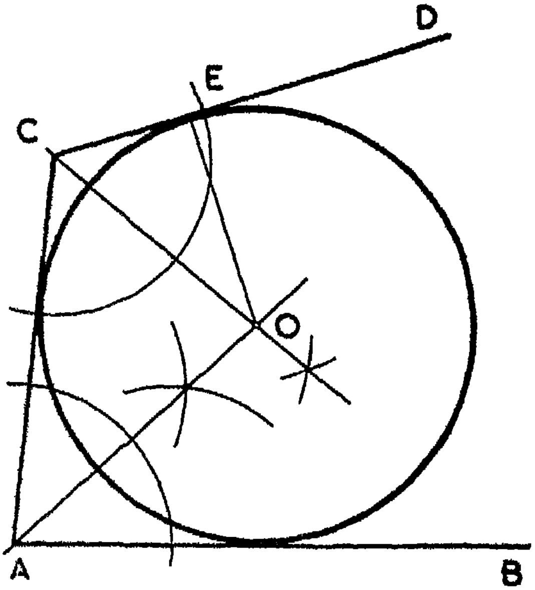


Fig. 4.11 Circle touching three given straight lines

With O as centre where the parallels intersect, draw the circle with radius r.

(*iii*) *To describe a circle touching three given straight lines AB, AC and CD, making angles with each other, Fig. 4.11.* Bisect the angles at A and C by lines meeting at O. Draw OE perpendicular to CD. With centre O and radius OE describe the circle.

(*iv*) *To describe a circle touching two converging lines AB and AC and passing through a given point D between them, Fig. 4.12.* Bisect the angle BAC by the line AM ; the centre of the circle must

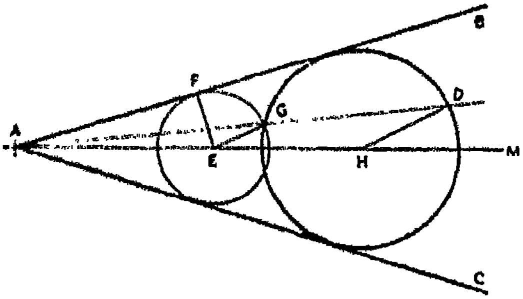


Fig. 4.12 Circle through a given point and touching two convergent lines

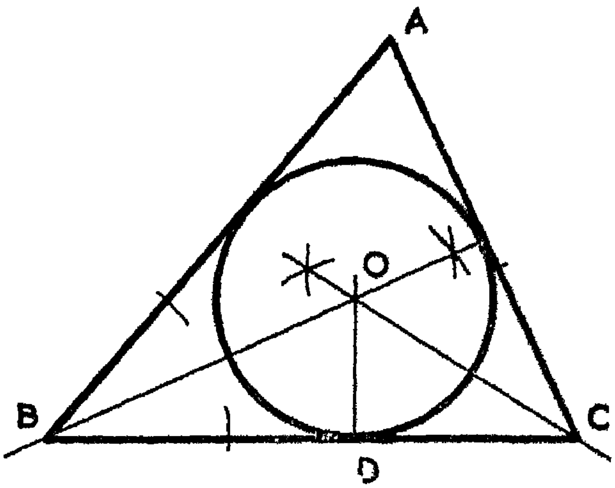


Fig. 4.13 Inscribed circle in a triangle

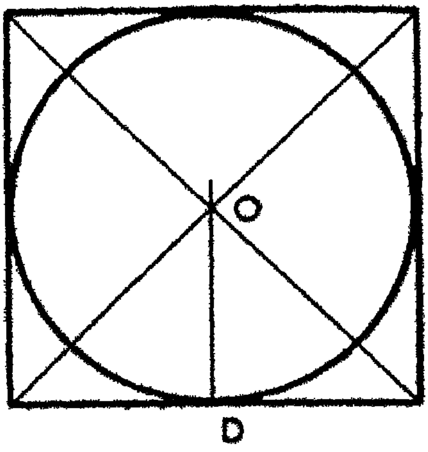


Fig. 4.14 Inscribed circle in a square

lie in this line. From any point E on line AM, draw EF perpendicular to AB, and describe a circle touching AB and AC. Join A to the given point D. AD cuts the circle at G. Draw EG, and from D draw DH parallel to GE. With centre H and radius HD describe the required circle.

(*v*) *To inscribe a circle in a given triangle ABC, Fig. 4.13.* Bisect any two angles ; the bisectors interesect at O the centre of the required circle. From O drop a perpendicular OD on to any side, say AC. With OD as radius describe the circle.

(*vi*) *To inscribe a circle in a square, Fig. 4.14.* Draw the diagonals to give the centre O. With O as centre and one-half the length of a side of the square as radius describe the circle.

(*vii*) *To inscribe a circle in any regular polygon, Fig. 4.15.* Bisect two of its angles to obtain O the centre of the circle. From O construct a perpendicular OA to one of the sides of the polygon. With O as centre and OA as radius draw the circle.

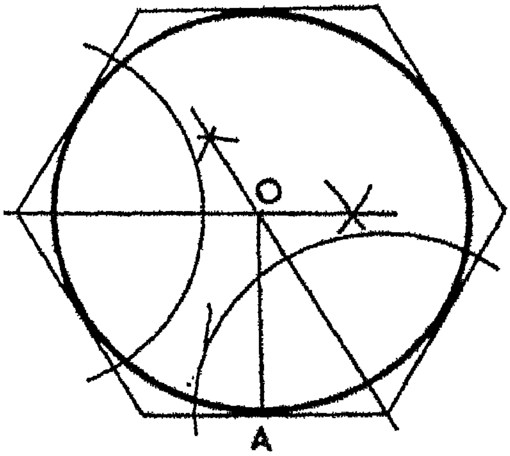


Fig. 4.15 Inscribed circle in a polygon

4.8 To Construct any Regular Polygon on a Given Straight Line

Let AB, Fig. 4.16, be the given straight line (the side of the polygon), and let the number of sides be, say, seven. Produce the line AB, and with A as centre and AB as radius, describe a semi-circle. Divide this into as many equal parts as the number of sides of the polygon—in this case, seven. The division of the semi-circle may

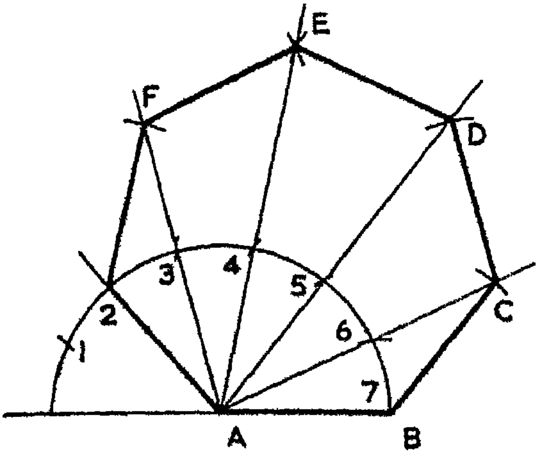


Fig. 4.16 Constructing a regular polygon of a given side

be done either with dividers or with protractor. Draw lines from A through the division points, 2, 3, 4, 5 and 6. Point 2, the second division point is always one of the vertices of the polygon, and line A2 is a side. With B as centre and AB as radius cut A6 at C. With C as centre and same radius AB cut A5 at D. The same procedure may be followed to obtain the other vertices of the polygon as shown.

4.9 To Inscribe Polygons in Circles

(*i*) *To inscribe a square in a given circle, Fig. 4.17.* Draw perpendicular diameters AC and BD. Their extremities are the vertices of the required square.

(*ii*) *To inscribe a regular pentagon in a given circle, Fig. 4.18.* Draw perpendicular diameters AC and BD intersecting at O. Bisect AO at E and with E as centre, and EB as radius, draw an arc cutting AC at F. With B as centre and BF as radius, draw an arc cutting the circle at G and H ; with the same radius BF, and with centres G and H cut the circle at L and K. Join the vertices B,G, L,K and H to obtain the required pentagon.

(*iii*) *To inscribe a regular hexagon in a given circle, Fig. 4-19.* Mark off by arcs, six points around the circle, equidistant as the radius of the circle. These points are the vertices of the required hexagon.

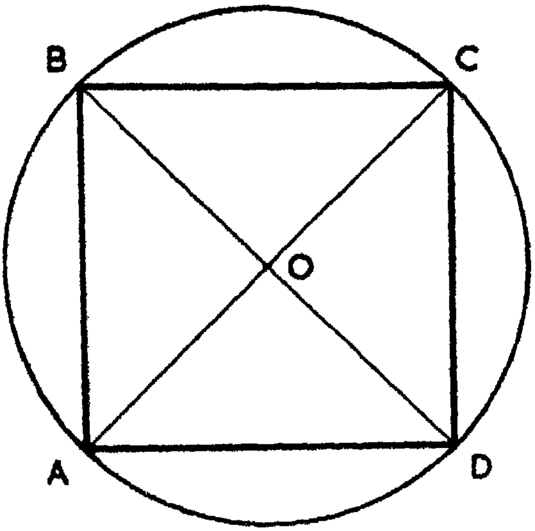


Fig. 4.17 Inscribed square in a circle

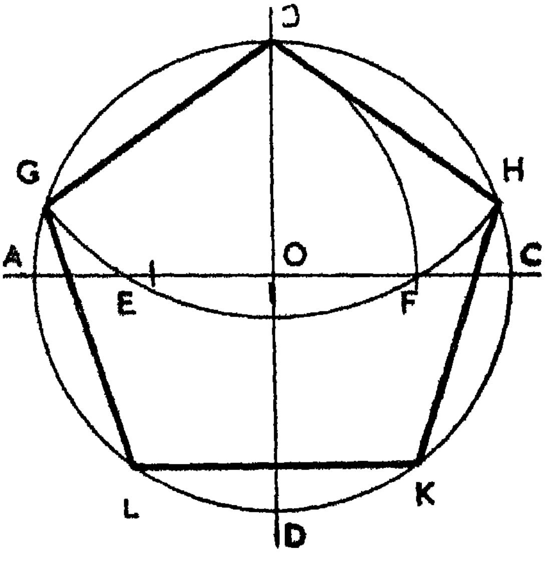


Fig. 4.18 Inscribed regular pentagon in a circle

(*iv*) *To inscribe a regular polygon of any number of sides in a given circle.* Determine the central angle subtended by

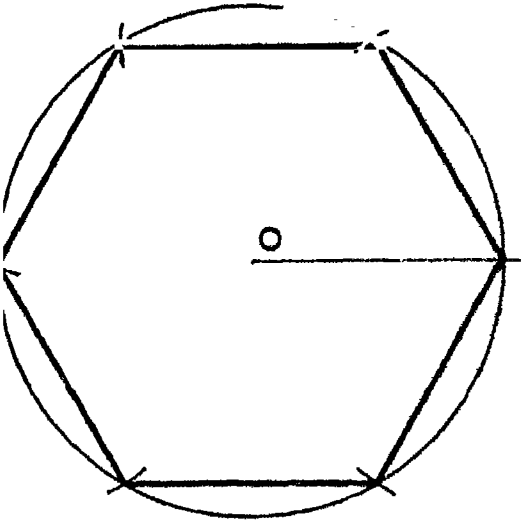


Fig. 4.19 Inscribed regular hexagon in a circle

any side of the polygon by dividing 360° by the number of sides. Lay off this angle successively round the centre of the circle by means of a protractor. The radii thus drawn, intersect the circle at vertices of the required polygon.

4.10 To Construct an Ellipse, the Major and Minor Axes being Given

Definition—An ellipse is a cruve for which the sum of the distances of any point on it from two fixed points, (F_1 and F_2), called the foci, is constant, Fig. 4-20. The line AB passing through the foci is called the *transverse* or *major axis*; its perpendicular bisector CD is called the minor axis or the *conjugate* of the major axis. Any line passing through the centre O and terminated by the curve is a *diameter* or *axis*. Any straight line perpendicular to the major axis is an *ordinate* (for example GH); GK is a *double ordinate*. A tangent is a line touching the curve at one point; a perpendicular to the tangent at the point of contact is a *normal*.

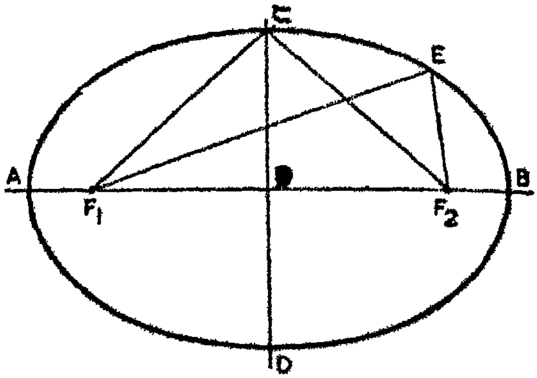


Fig. 4.20 Ellipse—thread method

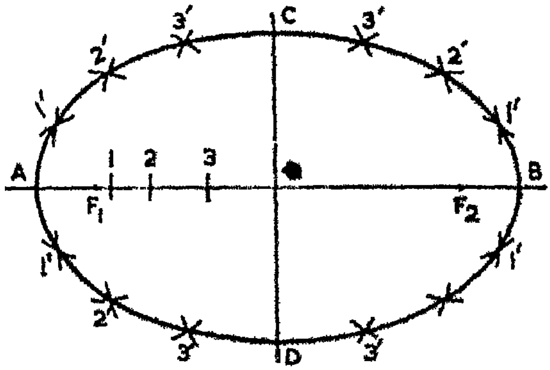


Fig. 4.21 Ellipse—Intersecting arcs method

(i) *To construct an ellipse the major and minor axes being given.*

Method (a)—thread method. Let AB and CD be the axes, Fig. 4.20. Let the centre be O, where the axes bisect each other at right angles. With radius AO and centre C describe an arc cutting AB in F_1 and F_2 (the foci). Take three pins, and fix them firmly at the points C, F_1 and F_2. Tie a piece of thread round these pins as shown by the lines CF_1, F_1 F_2 and F_2 C. Remove the pin at C, and replace it with a pencil point. Move the point of the pencil around, keeping the thread stretched. The curve described by the pencil is the ellipse.

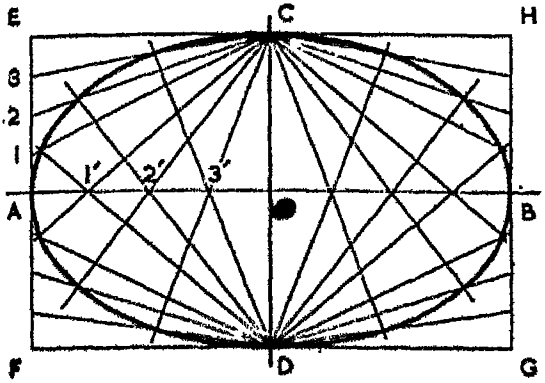


Fig. 4.22 Ellipse—intersecting lines method

Method (b)—intersecting arcs or foci method, Fig. 4.21. Place the axes as before. With radius AO and centre C obtain the foci. Take any number of points as 1, 2, 3, in F_1O. With radius B_1 and centres F_1 and F_2 describe arcs near points marked 1'. With radius A1 and the same centres (F_1 and F_2) intersect these arcs at 1'. Repeat the procedure to obtain points 2' and 3'. Through the points thus obtained draw the ellipse.

Method (c)—intersecting lines method, Fig. 4.22. Place the axes as before, and through the extremities draw the rectangle EFGH. Divide AE into any number of equal parts, say 4, by the points 1, 2 and 3 as shown. Join each of these points to C. Divide AO into the same number of equal parts by points 1', 2' and 3'. Draw lines from D through 1', 2' and 3', to intersect the lines C_1, C_2, C_3 ; these intersection points give the ellipse required. The procedure may be repeated to obtain the points of the ellipse in the other quadrants.

Method (d)—concentric circle method, Fig. 4.23. Place the axis as before and describe a circle on each. Divide one of the quadrants into any number of parts

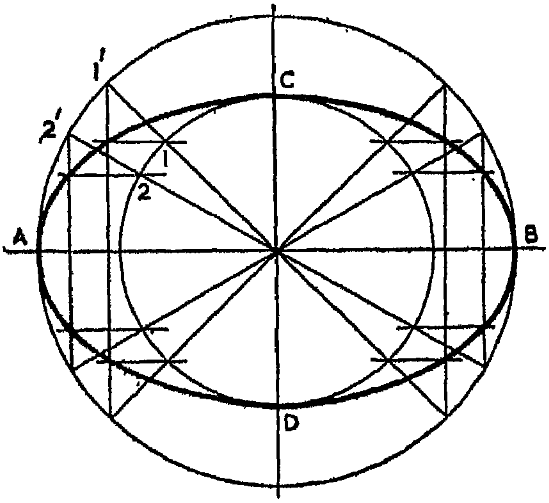


Fig. 4.23 Ellipse—concentric circle method

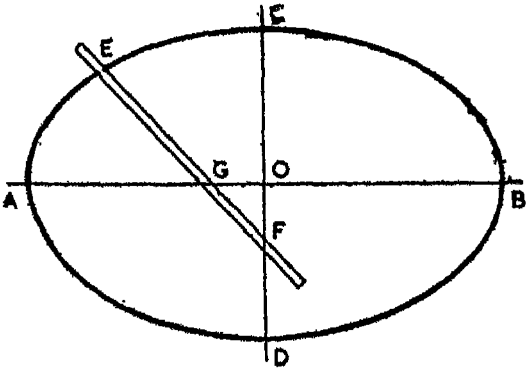


Fig. 4.24 Ellipse—straight edge method

and obtain the corresponding points by producing the radii. From points 1 and 2 on the smaller circle draw parallels to AB, and from points 1' and 2' on the larger circle draw parallels to CD to intersect the lines drawn parallel to AB. Draw the ellipse through these intersection points.

Method (e)—Straight edge or trammel method, Fig. 4.24. Place the axes as in method (d). On the straight edge or on a piece of paper mark EF equal to AO

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and EG equal to CO as shown. Place it so that G may be on the major axis and F on the minor axis. Then E will be a point on the curve. Move the straight edge, keeping G on the major axis, and F on the minor axis to obtain other points on the ellipse. Complete the ellipse by drawing a smooth curve through the points.

PROBLEMS

1. Draw a line 40 mm. long and bisect it using ruler and compasses only.
2. Draw a line 50 mm. long and bisect it using triangles only.
3. Draw a line 68 mm. long and divide it into five equal parts using ruler and compasses only.
4. Draw a line 78 mm. long and enlarge it to 8/5 times its length.
5. Draw a line 78 mm. long and reduce it to 3/5 times its length.
6. Draw a circle of diameter 55 mm. and draw a tangent passing through the crowning point of the circle (i.e. the topmost point of the circle), using ruler and compasses only.
7. Draw a circle of diameter 56 mm. and draw a tangent to the circle from a point which is 100 mm. to the right of the centre of the circle.
8. Draw a circle of 90 mm. diameter. Draw a tangent through the topmost point of the circle using ruler and compasses only and without using the centre of the circle.
9. Draw two circles of 95 mm. and 65 mm. diameters respectively with their centres 110 mm. and draw their (a) internal and (b) external common tangents.
10. Draw two straight lines converging at an angle of 30° and draw a circle of 35 mm. radius touching the two lines.
11. Draw a circle passing through a point P which is 75 mm. from the point of intersection of two lines converging at an angle of 30°. The point P is 15 mm. distant from one of the converging straight lines.
12. Construct a regular polygon of 9 sides, each 30 mm. long.
13. A regular pentagon has a side of 25 mm. Draw the inscribed circle.
14. Draw a regular hexagon of side 30 mm. and draw the inscribed circle.
15. Draw an ellipse whose major axis is 100 mm. and minor axis is 60 mm. by the following five methods : (a) thread methods, (b) intersecting arc method, (c) intersecting straight lines method, (d) concentric circle method and (e) straight edge (or trammel) method.

CHAPTER 5

Multiview Drawings

5.1 Introduction

Multiview drawings are drawings which represent many views of an object. It would be more accurate to describe them as *multiview orthographic projections* as explained below. Engineers have found it necessary and convenient to make multiview drawings for giving complete description of the objects they like to manufacture or construct. By means of multiview orthographic projections, we can describe the true shape and size of three dimensional objects on a two-dimensional plane sheet of drawing paper. The information given in engineering drawings are of two types (1) description of shape, and (2) description of size and other details of construction and finish. Description of shape is done by some systematic method of projection. Description of size and other details are dealt with under the heading "theory of dimensioning" later on in this chapter.

Projection—Projection of an object on a picture plane (i.e. the plane on which the drawing is made) is the method of obtaining a picture of the outline of the object as seen by the observer. In order to do this projection, lines called *projectors* (or visual rays) are assumed to be drawn from the eye of the observer to the outline of the object. The projectors are produced to meet the picture plane as shown in Fig. 5.1. If the points of intersection of the projectors on the picture plane are marked, an outline is obtained on the picture plane. This figure is called the *projection* or view of the object. The picture plane, if considered as transparent, may be placed between the eye and the object as shown in Fig. 5.2.

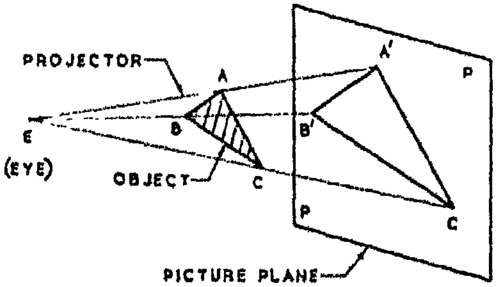


Fig. 5.1 Projection—object between eye and picture plane

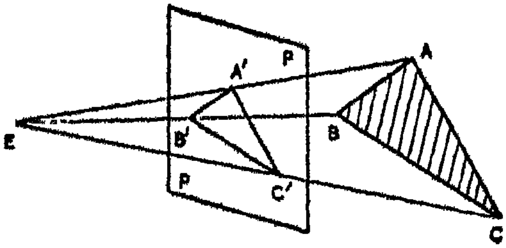


Fig. 5.2 Projection—picture plane between eye and object

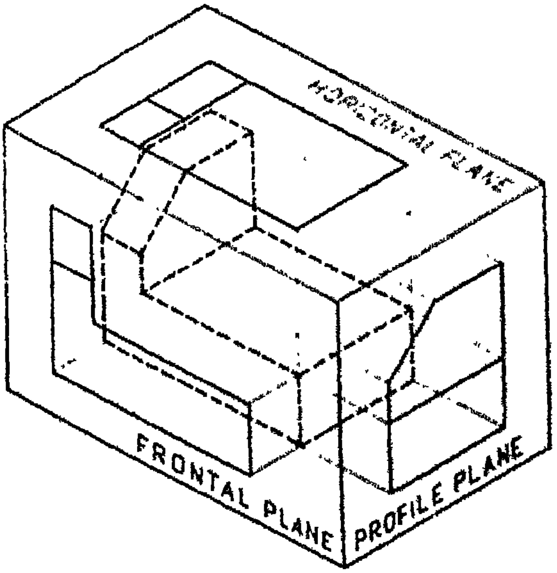


Fig. 5.3 The glass box

Projections are mainly of two types : (1) perspective projection, and (2) parallel projection.

Perspective Projection—In perspective projection the projectors converge to a point as shown in Fig. 5.1. This is also called *central*, *radial*, or *conical* projection. It does not show the true size of the object.

Parallel Projection—If the point to which the projectors converge is moved to an infinite distance from the object, the projectors become parallel and the projection is called parallel projection. If the projectors are parallel and also *perpendicular* to the picture plane (i.e., the plane of projection), the projection is known as *orthogonal* or *orthographic projection.*

Orthographic projection is the one most commonly used by engineers and unless otherwise stated, "projection" means orthographic projection only.

Multiview Orthographic Projection by the Glass Box Method—In order to obtain multiview drawings (i.e., multiplanar orthographic projections), it is usual to imagine the object enclosed in a rectangular box made of transparent plane sheets of glass with the principal face of the object parallel to the frontal plane of the box as shown in Fig. 5.3. The observer is outside the box and takes the views or projections of the object on the outside of the box. The views are always taken so that the projectors are at right angles to the planes of projection. All the sides, excepting the rear one, of the glass box are assumed to be hinged to the frontal plane and *opened* out so that all the five views lie in the same plane as the frontal plane. We thus get the multiplanar orthographic projection of the object on one flat sheet as shown in Fig. 5.4. If necessary, the rear view may also be revolved (turned round) and placed on the same plane as the frontal plane as shown in Fig. 5.4. Ordinarily, the rear and the bottom views are rarely necessary. Only three views, namely, the front view, the top view and one of the side views are usually given.

The top view is also called the *plane*. The side view is also known as the *profile or end view*. The front view is referred to as *front elevation* or simply *elevation*.

An orthographic projection shows the true size and shape of the surface of the object which is parallel to the plan of projection. It does not however show depth of the object which is perpendicular to the picture plane. Hence additional projections or views are necessary to complete the description of the object.

Two views mutually at right angles to each other are enough to describe any three-dimensional object completely. But three or more views may be given for greater clarity and easy understanding of the view of the object. The usual practice is to give three views, namely, the front, top and one side view.

5.2 Uniplanar Orthographic Projection

Sometimes when all the three dimensions (height, width and depth) of the object are required to be shown in a single view, i.e. on one plane of projection, instead of keeping the principal face of the object parallel to the picture plane,

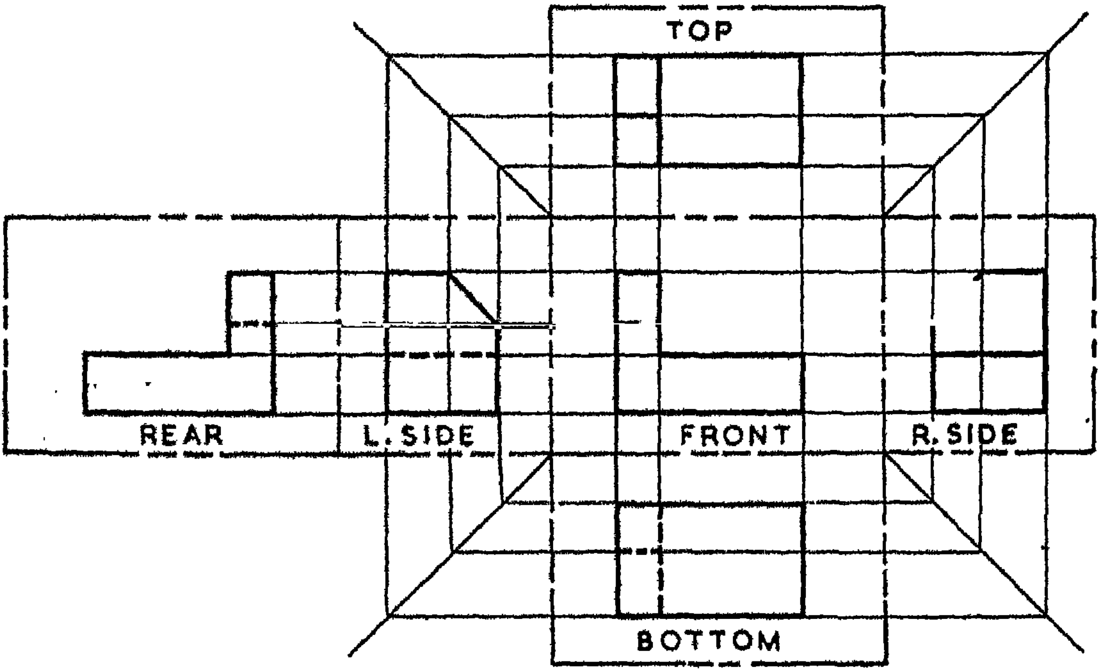


Fig. 5.4 The glass box opened out

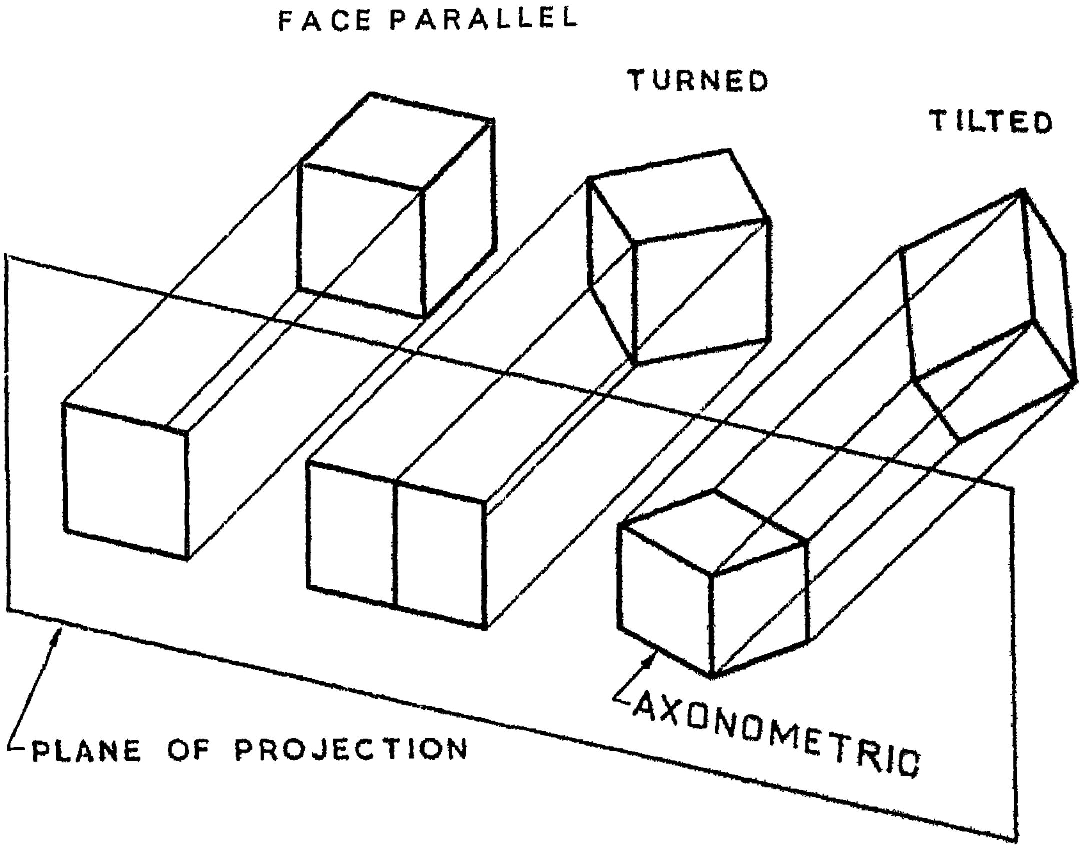


Fig. 5.5 The axonometric projection

it is kept revolved and tilted as shown in Fig. 5.5. The orthographic projection of such an object is called a *uniplanar orthographic projection* or *axonometric projection.* Such a projection does not give the true size and shape of the object, although a three-dimensional picture is obtained. There are many types of axonometric projections of which the "*isometric projection*" is the one most commonly used. The isometric projection is dealt with in chapter 7.

5.3 Comparison of First Angle and Third Angle Projections

There are three principal planes of projection mutually at right angles to each other, Fig. 5.6. These are the *frontal*, *horizontal* and *profile planes*; these are also known as the *co-ordinate*

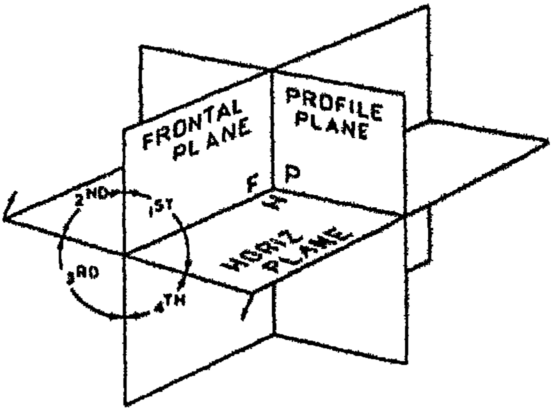


Fig. 5.6 The principle planes of projection

planes. Both the frontal and profile planes are vertical. They are assumed to extend indefinitely and intersect in straight lines called the *co-ordinate axes*. The line of intersection of the frontal and horizontal planes is the x-axis ; the line of intersection of the frontal and profile planes is the y-axis ; and the line of intersection of the horizontal and profile planes is the z-axis. These axes are also known as the reference lines or fold lines.

The *origin* is the point of intersection of the co-ordinate axes. There are four quadrants formed by the intersection of the frontal and horizontal planes. These are known as *the first, second, third and fourth angles*. The eight solid (or space) angles formed between the three planes of projection are called *the octants*.

The projections of the object on the three principal planes of projection are considered as "*first angle projection*" or "*third angle projection*" according as the object is placed in the first quadrant or in the third quadrant.

In multiview drawings the projections on the principal planes are revolved through 90 degrees so as to coincide with the frontal plane. The standard conventional method of revolution, as shown in Fig. 5.6, is to revolve the horizontal plane about the x-axis to coincide with the frontal plane by *opening* the first and third quadrants (or by *closing* the second and fourth quadrants), and to revolve the profile plane about the y-axis away from the object so as to coincide with the frontal plane.

Obviously, if the object were placed in the second or fourth quadrant, the front and top views will overlap each other after the planes of projection are revolved through 90 degrees as stated above. Hence, second and fourth angle projections are rarely used.

Third Angle Projection—The projections obtained in Fig. 5.4, by the glass-box method as already described, are the third angle projections of the object. In the third angle projection the plane of projection is between the object and the observer.

Third angle projection may be defined as that in which each view is so placed that it represents the side of the object *near* to it in the adjacent view. In other words, parts of the object nearest to the observer in the front view are placed nearest to the front view in the adjacent views.

First Angle Projection—The projection obtained when the object is between the observer and the plane of projection, is called the first angle projection. Here the observer may be assumed to be inside the imaginary glass box and the projections are on the inside faces of the box which are beyond the object.

First angle projection may be defined as that in which each view is placed in such a manner that it represents the side of the object *remote* from it in the adjacent view. In other words, parts of the object nearest to the observer in the front view are farthest from the front view in the adjacent views.

Examples of third angle and first angle projections of the same object are shown in Figs. 5.7 and 5.8, respectively. It will be observed that in the third angle projection, the right side view is on the right of the front view ; the top view is on the top of the front view ; *thus the views are placed in their natural relative positions*. This fact is considered as

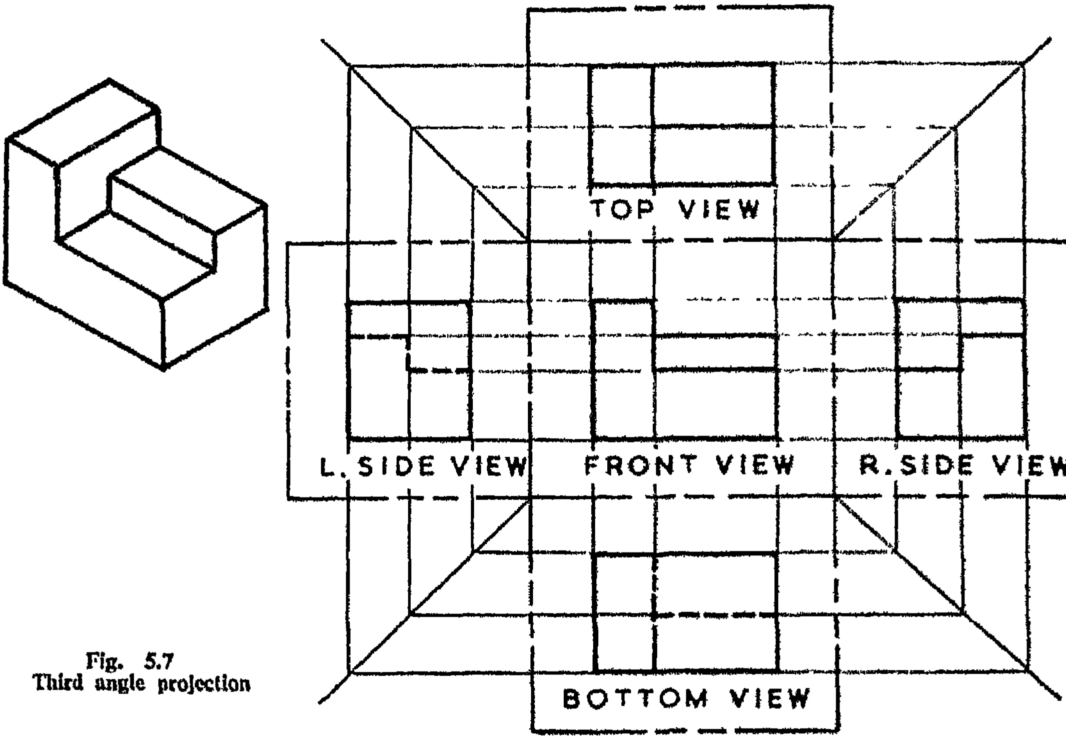


Fig. 5.7
Third angle projection

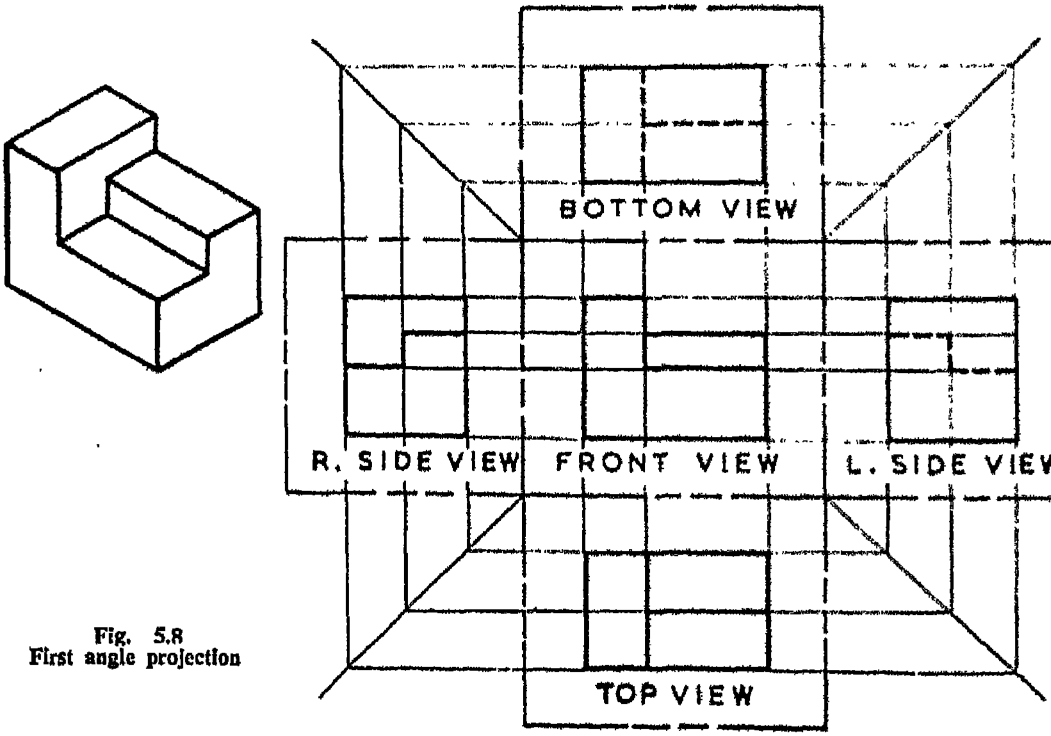


Fig. 5.8
First angle projection

the main advantage of the third angle projection. On the other hand, in the first angle projection, Fig. 5.8, the right side view is on the left of the front view, the top view is at the bottom of the front view, and the left side view is on the right of the front view.

The third angle projection has been adopted as the standard method of projection for general engineering drawings in India and also in the United States of America. The method of first angle projection, however, is used mostly in structural and architectural drawings. First angle projection is the standard method in England and other European countries for all drawings.

For building drawings, the Indian Standards recommend a combination of first and third angle projections; i.e. in relation to the elevation, the end views are so placed that they are in the third angle projection and plan views are in the first angle projection.

5.4 Points, Lines and Surfaces in Multiview Projection

DEFINITIONS :

A *line* is a succession of points so that it has length but no breadth or thickness. Lines may be straight lines, plane curves or space curves. The most common line is the straight line—the shortest distance between any two points—and hence, unless otherwise stated, a line means a straight line.

An *inclined line* is any line which is parallel either to the frontal or profile plane, but it is neither horizontal nor vertical.

An *oblique line* is any line which is not parallel to any of the co-ordinate planes.

The inclination of a line to any plane is the angle between the line and its projection on that plane.

The traces of a line are the points of intersection in which the line or line produced meets the co-ordinate planes.

The slope of a line is the angle between the line and its horizontal projection.

An *inclined plane* is any plane which is perpendicular to one of the principal planes but not parallel to any of them. The projection of an inclined plane is a line on the principal plane of projection to which it is perpendicular.

An *oblique plane* is any plane which is neither parallel nor perpendicular to any of the principal planes of projection.

The traces of a plane are the lines in which a plane meets the co-ordinate planes; the intersection with the frontal plane is called the *frontal trace*; that with the horizontal plane, the *horizontal trace*; and that with the profile plane, the *profile trace*.

Dihedral angle is the angle between any two planes as measured between two straight lines, one in each plane, drawn from a common point in the line of intersection of the planes and at right angles to it.

A surface is that which has the dimensions of an area like the boundaries of solids. A surface is generated by the motion of a geometric line either straight or curved. The geometric line is called the *generatrix*. Any position of the generatrix is called an *element of the surface*.

A ruled surface is a surface that can be generated by a straight line; e.g., a plane, a singly curved surface or a warped surface.

A *plane* is generated by a straight line moving parallel to itself with one end of the generatrix moving along another straight line.

A *singly curved surface* is a ruled surface which is developable ; i.e., a surface which can be unrolled or spread flat to coincide with a plane surface. Two adjacent positions of the generatrix may be parallel or intersecting ; e.g., the curved surface of a cylinder or a cone.

A *warped surface* is a non-developable ruled surface ; i.e., the consecutive straight line elements of the surface do not lie on a plane and are neither parallel nor intersecting ; e.g., a hyperboloid of revolution.

A *doubly curved surface* is generated by moving a curved line ; it has no straight element ; e.g., sphere, torus.

A *surface of revolution* is generated by rotating a straight or curved line about an axis. If the straight line generatrix is either parallel to or intersecting the axis, a singly curved surface is generated. If the straight line generatrix is neither parallel to, nor intersecting the axis, a warped surface, hyperboloid of revolution, is generated. A hyperboloid of revolution may also be generated by rotating a hyperbola about an axis in its own plane.

Basic Principles of Orthographic Projection—It is important to remember the following basic principles of multiview orthographic projections :

1. The top and front views of any point of an object must be in the same vertical line ; the profile and front views of any point must be in the same horizontal line.
2. The front view of a point is equivalent to giving the x and y co-ordinates of the point of the object ; the top view, its x and z co-ordinates ; and profile view, its y and z co-ordinates.
3. The projection of a plane figure on a plane parallel to the figure shows the true size and shape of the figure.

Since only three co-ordinates are required to locate a point in space any two views are sufficient to locate or describe a point completely. Hence the shape of any line or surface of an object in any view may be drawn if we know how to locate any point of the object in any view by knowing its co-ordinates.

Notation—The projections of a point may be distinguished with a subscript f, h, p or a, to indicate the plane of projection on which it is projected. Thus A_f stands for projection of point A, on the frontal plane; A_h, on the horizontal plane ; A_p, on the profile plane ; and A_a on the auxiliary plane. The subscripts are unnecessary if the axes of revolution (or the folding lines) of the planes of projection are otherwise indicated. The axes of revolution are indicated by a long line broken by two short dashes. The planes of projection on either side of the axis are denoted by the letters F, H, P or A, indicating the frontal (F), the horizontal (H), the profile (P) or the auxiliary (A) plane, respectively ; these planes may also be referred to by their abbreviations F.P., H.P., P.P., and A.P. The folding lines are identified by the letters indicating the adjacent planes ; e.g., the FH line is the folding line between the F and H planes.

A few examples to illustrate the above principles are worked out. The student should carefully learn to visualize the actual positions of the points in space, and also the true shape of the lines and surfaces of the object, in relation to the principal planes of projection, which may be considered as the sides of the imaginary glass box. Only the third angle projection is used, unless otherwise indicated.

Example 1 (Fig. 5.9)

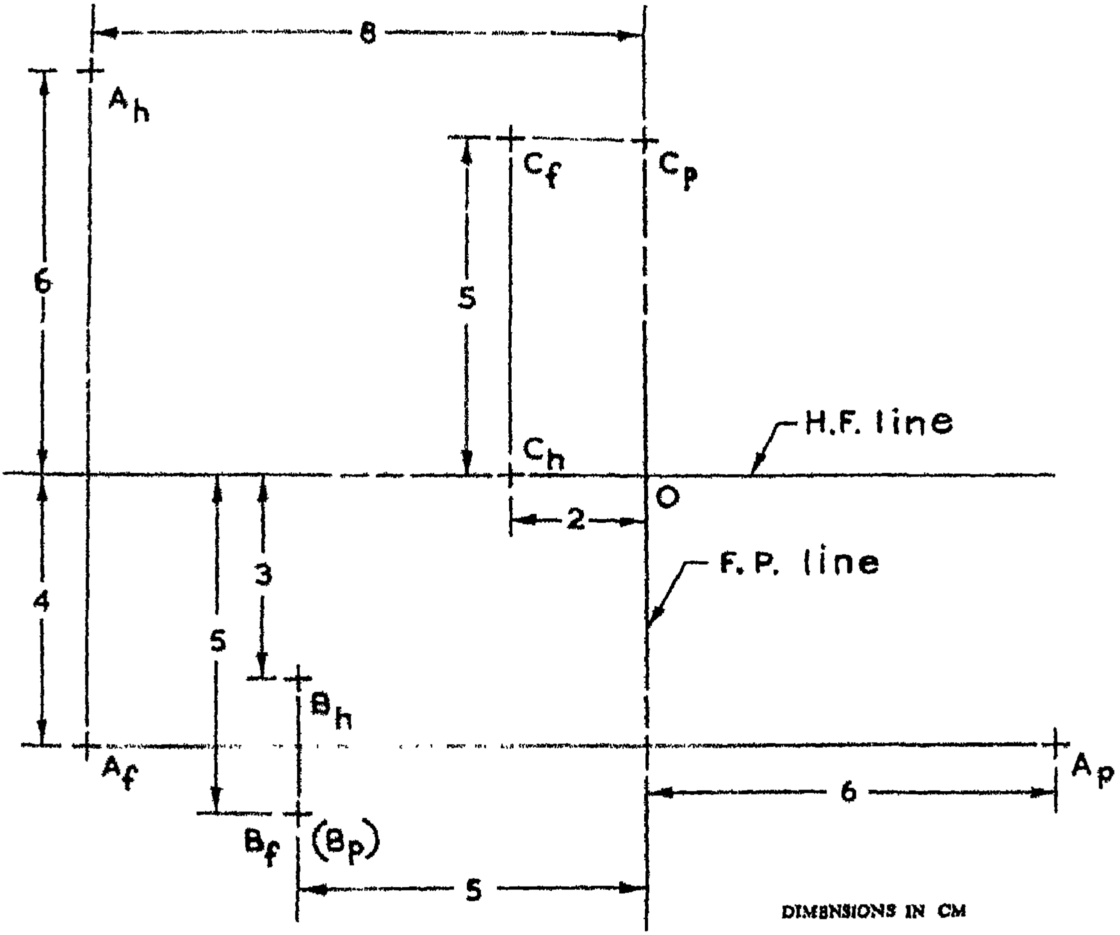
To find the projections of the following points on the F.P., H.P. and P.P :

A, 6 cm behind the F.P., 4 cm below the H.P. and 8 cm to the left of the P.P.

B, 3 cm in front of the F. P., 5 cm below the H.P. and 5 cm to the left of the P.P.

C, zero cm in front of the F.P., 5 cm above the H.P. and 2 cm to the left of the P.P.

The point A is, therefore, in the third quadrant. The front view A_f is 4 cm below the FH folding line ; its top view A_h is



DIMENSIONS IN CM

Fig. 5.9 Example—projection of points

6 cm above the FH line ; and its profile view A_p is 6 cm to the right of the FP line. A_f and A_h are 8 cm to the left of the FP line.

The projections of the other points B and C are similarly located in the Fig. 5.9. The actual point B is situated in the fourth quadrant and the actual point C lies on the frontal plane between the first and second quadrants.

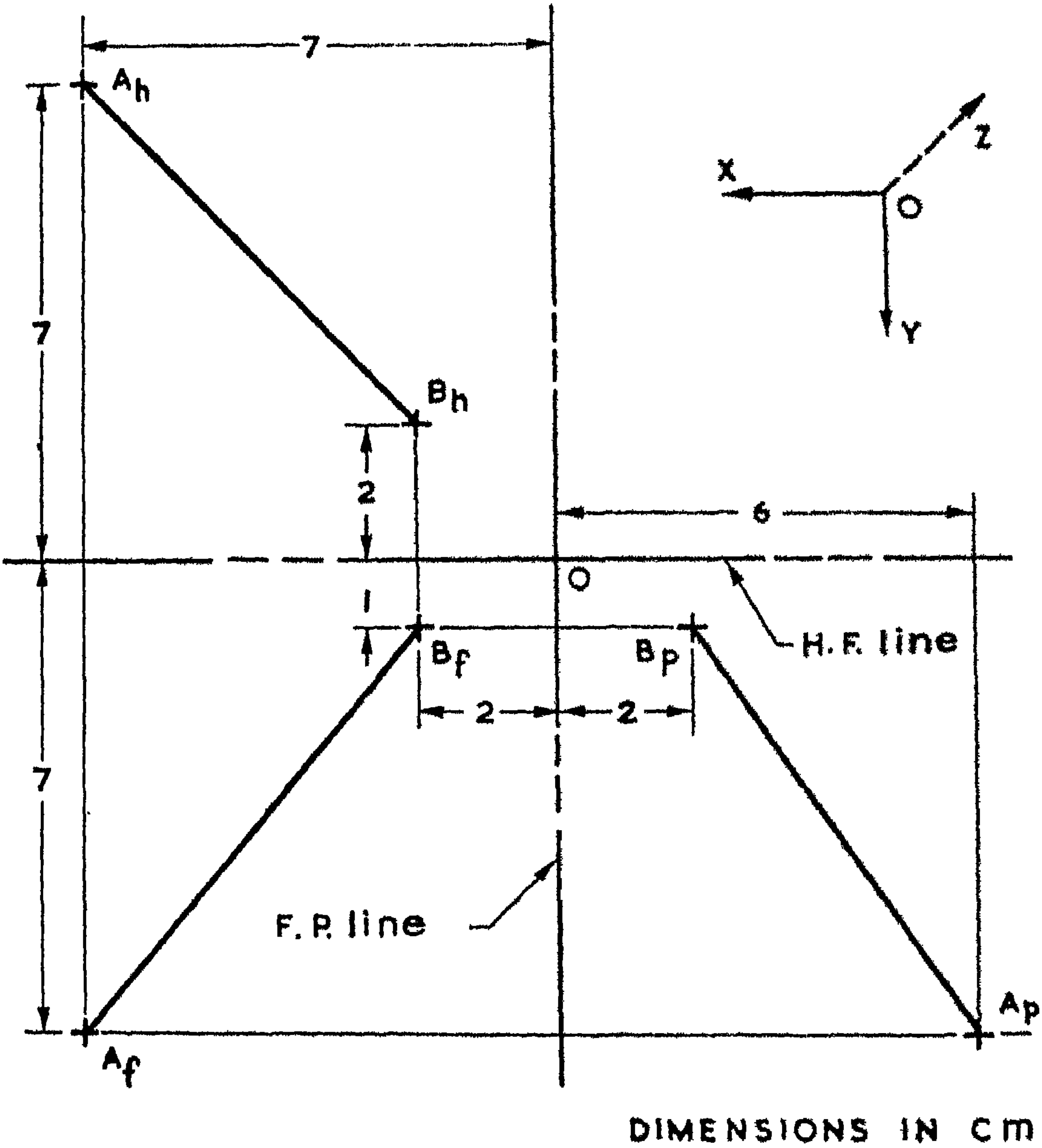


Fig. 5.10 Example—projection of lines

Example 2 (Fig. 5.10)

Draw the projections of an oblique line whose end points are A (7, 7, 6) and B (2, 1, 2) with respect to the co-ordinates (positive) indicated on the figures ; z-axis is perpendicular to the xy plane and the direction pointing into the paper is taken as positive.

The points A_f, A_h, A_p, B_f, B_h, B_p are located as in the above example and the lines A_f, B_f A_hB_h and A_pB_p are drawn to represent the projections of the line AB in the three views.

Example 3 (Fig. 5.11)

To find the true length of the line AB of example 2, from the given projections of the line.

Rotate the line AB about the point B, without altering the height of A or B, so that AB becomes parallel to the frontal plan ; the new top view is A'_hB_h. The

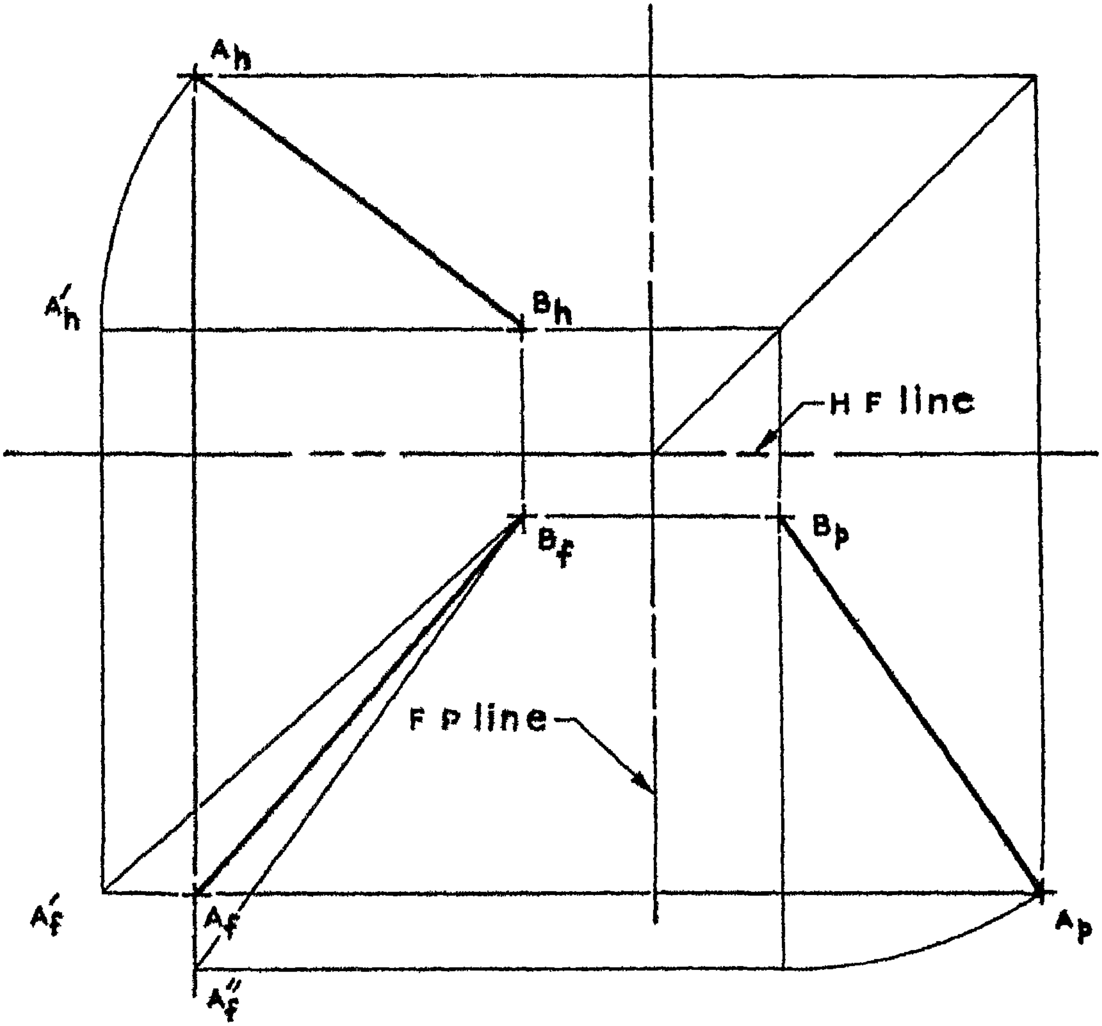


Fig. 5.11 Example—true length of lines

new front view, therefore, is A'_fB_f which is the true length of AB, since the line is parallel to the frontal plane.

Alternatively, the profile view A_pB_p may be rotated about B_p, without changing the distance of the points from the profile plane, to the new position A'_pB_p which is parallel to the FP line. The new elevation A''_fB_f is also the true length of the line AB.

Example 4 (Fig. 5.12)

To find the true shape of a plane triangle from the given top and front views.

The true lengths of the three sides are found as in example 3, and the required triangle ABC is constructed with the true sides as shown in the figure.

Any plane rectilinear figure may be divided into a number of triangles. Hence, extending the above method, the true

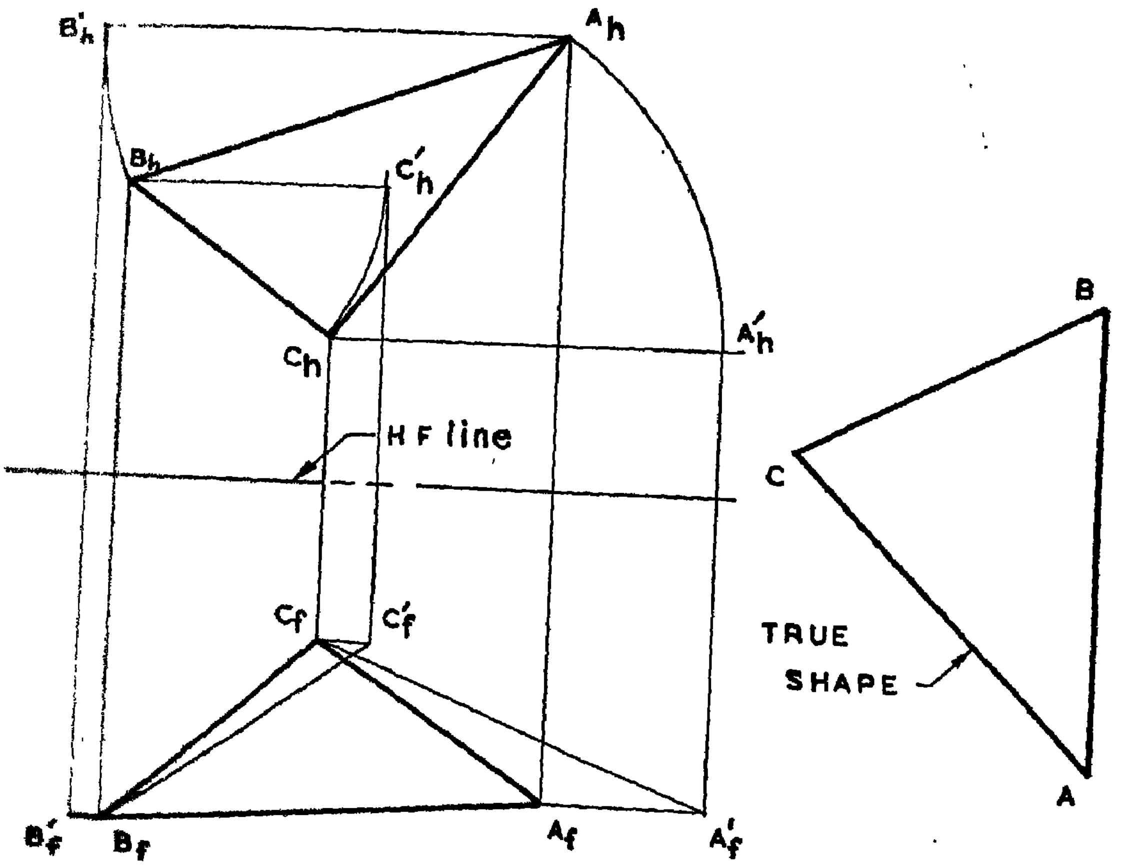


Fig. 5.12 Example—true shape of a triangle

shape of any plane rectilinear figure may be found if two views mutually at right angles are given.

5.5 Sections

Sectional views are necessary to understand the interior construction details of an object. For instance, the multiview drawings of an uncut orange will not help in describing the interior features of the orange ; but if the fruit is cut by a plane surface and one portion is removed, to expose the cut surface of the other part, we see the sectional view of the fruit, which shows the interior details.

A sectional elevation of an object and its top view are shown in Fig. 5.13. The top view shows the cutting plane line AA in the conventional manner, and the direction of viewing is indicated by the arrowheads. The sectional elevation is drawn by assuming that the front half of the object is removed. When the view is completely in section it is called a *full section.* Sometimes, the cutting plane stops at the centre and only half of the view is shown in section as in Fig. 5.14. This view is called *half section.* Sometimes, the details of construction of

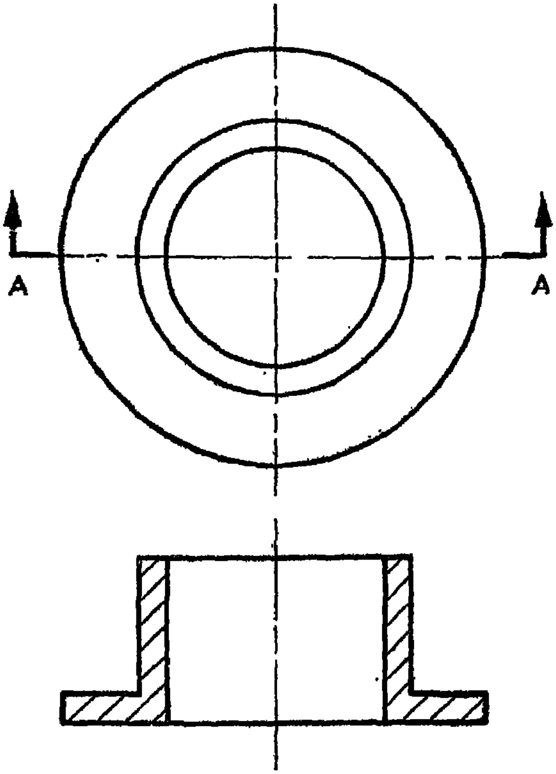


Fig. 5.13 Sectional elevation

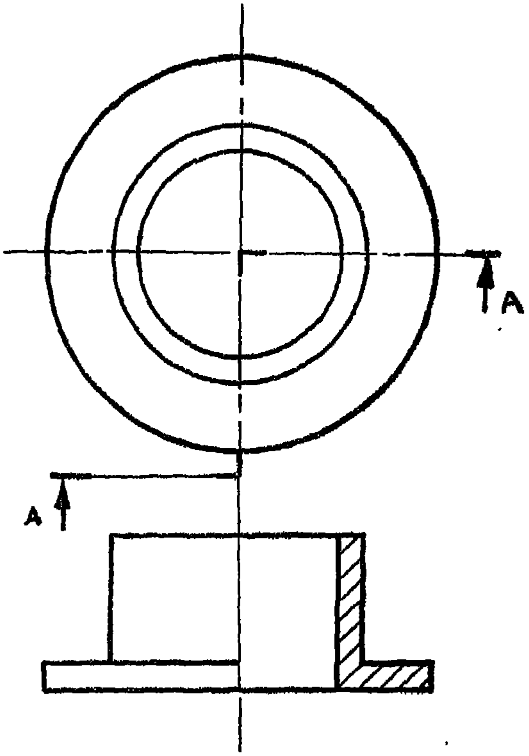


Fig. 5.14 Half section

the interior may be shown as in Fig. 5.15, by just showing only a small irregular portion as broken exposing the interior. Such views are known as *broken out sections* or *local sections.*

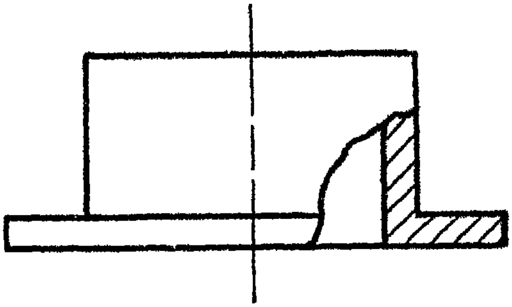


Fig. 5.15 Broken out section

Hatching—Hatching is used to show the materials in section. It is made by thin lines at a well defined angle, preferably 45 degrees, to the axis or to the main outline of the section, Fig. 5.16.

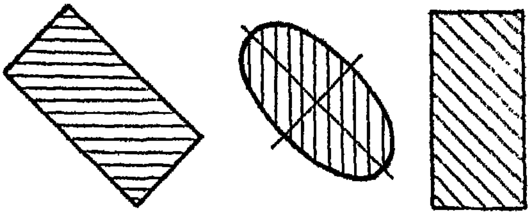


Fig. 5.16 Hatching

Separated sections of a single component are hatched in an identical direction. On a second part, adjacent to the first, the section lines should be drawn at an angle of 45 degrees in the opposite direction, Fig. 5.17. On a third part, adjacent to the first two, the section lines should be drawn at an angle of 30 degrees or 60 degrees with the main outlines of the view, Fig. 5.17.

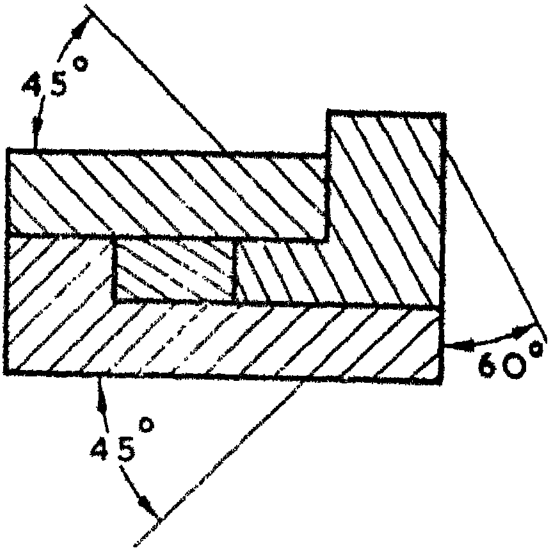


Fig. 5.17 Hatching adjacent sections

Spacing between the hatching lines should be in proportion to the size of the hatched section ; i.e. the spacing of section lines should be closed in small areas and wider apart in larger areas. For large areas, the hatching may be limited to a small zone near the outline of the hatched area, Fig. 5.18.

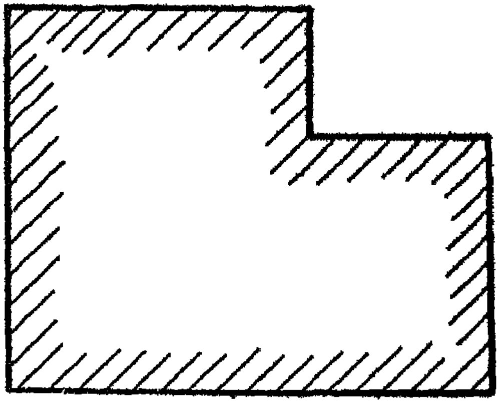


Fig. 5.18 Hatching large areas

Hidden edges should not be shown in hatched areas unless necessary for clarity.

Revolved Sections—The cross-section of a part of an object, such as a bar, arm, spoke, rib or flange or other elongated part may be shown on the main general elevation by revolving the cross-section through 90 degrees at the place of the section itself. Fig. 5.19.

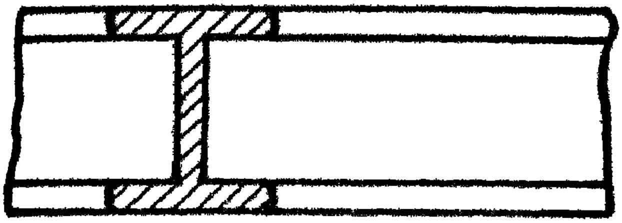


Fig. 5.19 Revolved section

Removed Sections—Sometimes, the cross-section, revolved through 90 degrees, is shown removed from the main view for greater clarity. Fig. 5.20.

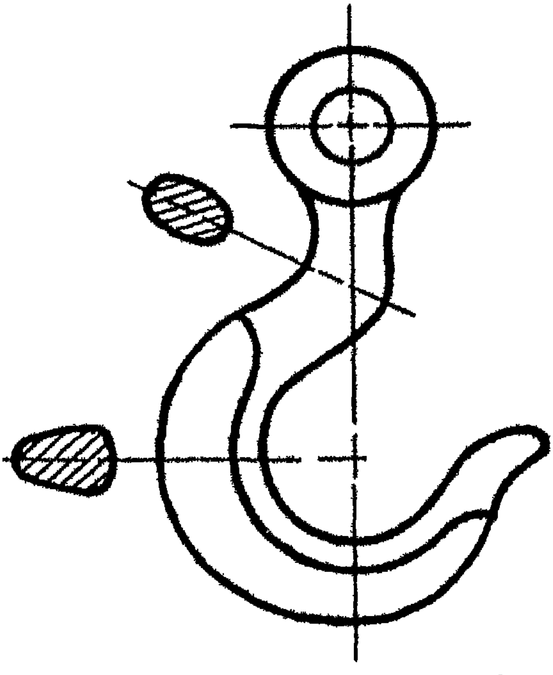


Fig. 5.20 Removed sections

EXCEPTIONAL CASES:

The following are some of the conventions used for convenience and simplicity :

(1) *Parts not sectioned*—Shafts, bolts, nuts, rivets, balls, cotters, keys, pins, spokes, gear teeth, ribs and webs, are not to be shown in section although the cutting plane passes through them, Fig. 5.21.

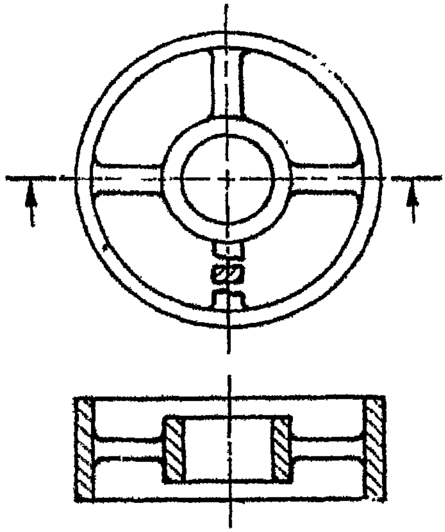


Fig. 5.21 Convention—parts not sectioned

(2) *Aligned Section*—Any symmetrical part having odd number of spokes, ribs or holes will give a true section which is rather confusing or complicated. In such cases, the unsymmetrical features are revolved to coincide with the symmetrical sectional

plane for giving a simpler projection, Fig. 5.22.

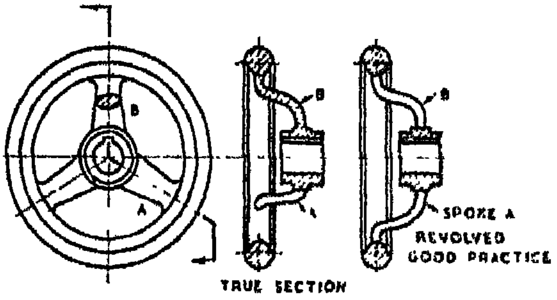


Fig. 5.22 Convention—simplified curve of intersection

(3) *Intersections in section*—When a section is drawn through an intersection in which the exact figure or curve of intersection is small or of no consequence, the figure or curve of intersection may be simplified as shown in Fig. 5.23.

5.6 Auxiliary Views and Revolutions

Auxiliary views are helpful additional views. Auxiliary views are required to find the true size and shape of surfaces which are not parallel to any of the six main planes of projection of the imaginary glass box. The projection of the

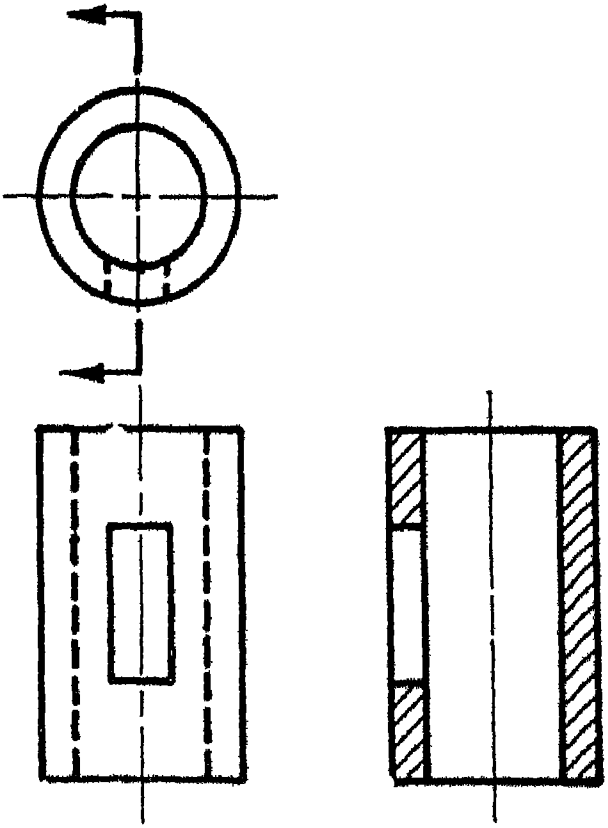


Fig. 5.23 Convention—simplified curve of intersection

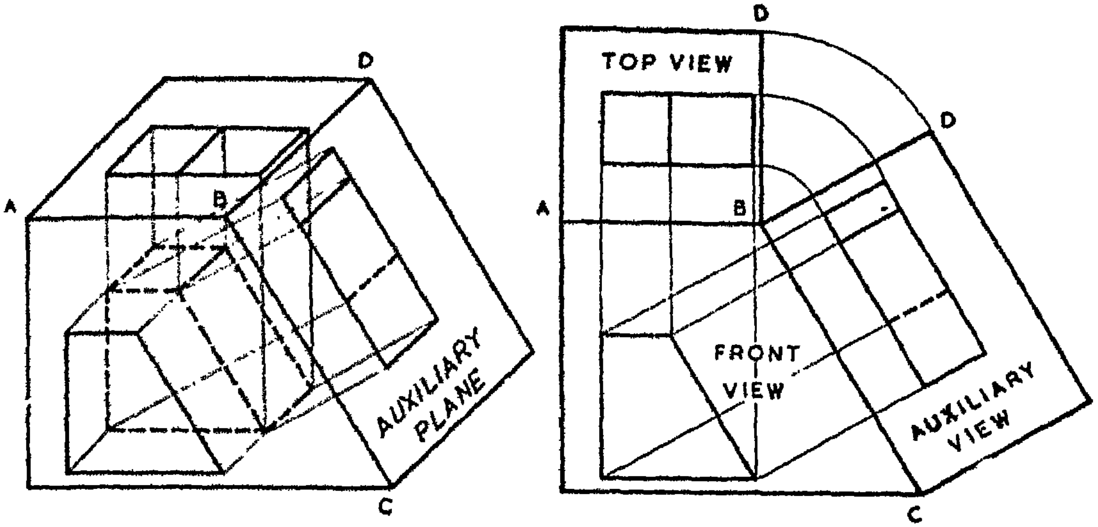


Fig. 5.24 Auxiliary view obtained by opening out glass box with auxiliary plane

inclined surface on a picture plane parallel to it shows its true size and shape. This picture plane is called the *auxiliary plane* and the projection on that plane is known as the auxiliary view, Fig. 5.24. Usually only partial or local auxiliary views are shown; i.e., only the inclined surface of the object which is parallel to the auxiliary plane is shown. This is just to avoid a complicated view of the object which is not necessary. The imaginary auxiliary plane, if perpendicular to one of the principal planes of projection, is called the *primary auxiliary* ; if it is inclined to all the principal planes (i.e., if oblique), it is called the *secondary auxiliary plane*. Only primary auxiliary views are dealt with in this book. The primary auxiliary plane is assumed to be hinged to one of the principal planes to which it is perpendicular. It is opened out through 90 degrees to coincide with the principal plane.

Revolution means revolving the object about an axis to obtain a view that shows the true size and shape of its inclined surface, as shown in Fig. 5.25.

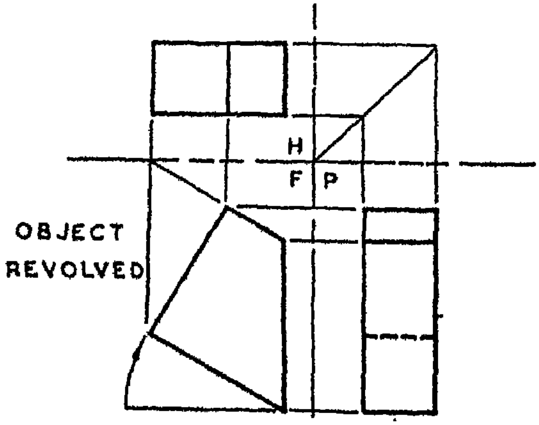


Fig. 5.25 Revolution of object

For an auxiliary view, the observer shifts his position with respect to the object, to obtain the true view of the inclined surface. In the method of *revolution*, the same true view is obtained by revolving the object relative to the observer who remains stationary.

5.7 The Making of Working Drawings

The final drawings, used in the workshops to manufacture the finished machine part, or used by the field engineer to construct the finished structure or to assemble the finished machine, are called the *working drawings*. The working drawing of a machine part, for instance, gives all the necessary information such as the number of pieces required, the material to be used, the shape details, the size details, the permissible tolerances, the method of manufacture, the kind of finish, the part number to be marked with, and such other details.

Working drawings may be either detailed drawings of individual parts, or assembly drawings of complete machines. Assembly drawings show clearly how the component parts of a machine are fitted together for proper working of the machine.

5.8 Theory of Dimensioning

Engineering structures or machine parts can be considered as composed of simple basic geometrical solids, like prisms, cylinders, pyramids, cones and spheres, or parts of such solids. Dimensioning any object is, therefore, equivalent to dimensioning these basic forms of solids. These forms may occur either on the exterior or in the interior of the object considered ; e.g., a shaft is an exterior cylinder while a circular hole is an interior cylinder.

Linear dimensions on engineering drawings are of two types : (1) size dimensions, and (2) location dimensions. These dimensions must be clearly given on the drawing so that it will never be necessary for the workman to calculate, scale, or guess any dimension in order to make the part. Dimensions should be given to finished surfaces.

Size Dimensions—Two of the three main dimensions (height, width and depth) are given on the principal view which shows the features clearly and the third dimension is shown on a second view.

Location Dimensions—These are given either from two finished surfaces mutually at right angles, or from hole centre to hole centre and surface to hole centre.

The main principles and illustrated examples on dimensioning have already been given in article 3.6. The student should follow them carefully.

5.9 Notes and Titles

Notes are frequently necessary to indicate on drawings, the number of pieces required, the number of similar features on a part, the nature of manufacturing operations, and other details of material or type of finish. Such additional information, which do not come under the category of shape or size description, are given in the form of short notes in simple, neat and legible lettering. Notes should be carefully worded to avoid misinterpretation and should be brief. Standard abbreviations and symbols (see appendix I) may be used to minimize the length of notes.

Titles are generally given at the bottom right hand corner of the drawing sheets in rectangular "boxes" or frames. The purpose of the title block is to show the name of the object or structure shown, the name of the organization, the date, and the scale. Sometimes, additional information such as the name of the designer, draughtsman, tracer, checker, and the name of the approving authority and such other details are also included. The name of the object or structure shown on the drawing should be lettered more prominently than other data. On engineering drawings, lettering is generally done in single stroke Gothic. On display drawings, other styles of thick filled-in lettering may be used. It is usual to arrange the lettering symmetrically about the vertical centre line of the title block, for pleasing appearance.

5.10 Fits and Tolerances

Modern methods of manufacture, say, of any machine aim at interchangeability and mass production of many mating parts. Mating parts are any two parts that unite or fit together, e.g. shaft and bearing, bolt and nut, or cylinder and piston. In the manufacture of any part its dimension cannot be made exactly as given in the theoretical design. A certain margin of error in dimension has to be allowed for in the manufacturing processes, within certain limits. The limits depend on the purpose of the part to be manufactured. The limits give the maximum and minimum size of the length of a part or the diameter of a hole, Fig. 5.26. The difference between the two limits of a *dimension* of a part is called the *tolerance* on that dimension. In other words, tolerance is the amount of variation permissible on a dimension. *The basic size* is the theoretical dimension from which the limits are derived. The limiting dimensions are given in decimal form. Tolerances are said to be *unilateral* if they lie only on one side of the basic dimension, or *bilateral* if they lie on both sides of the basic dimension.

Allowance is the clearance (i.e., clear distance) between the mating parts, Fig. 5.26. The allowance may range from a minimum to a maximum clearance as shown in the figure.

Fit is the degree of tightness between two mating parts. There are three main types of fits : (1) clearance fit, (2) interference fit, and (3) transition fit.

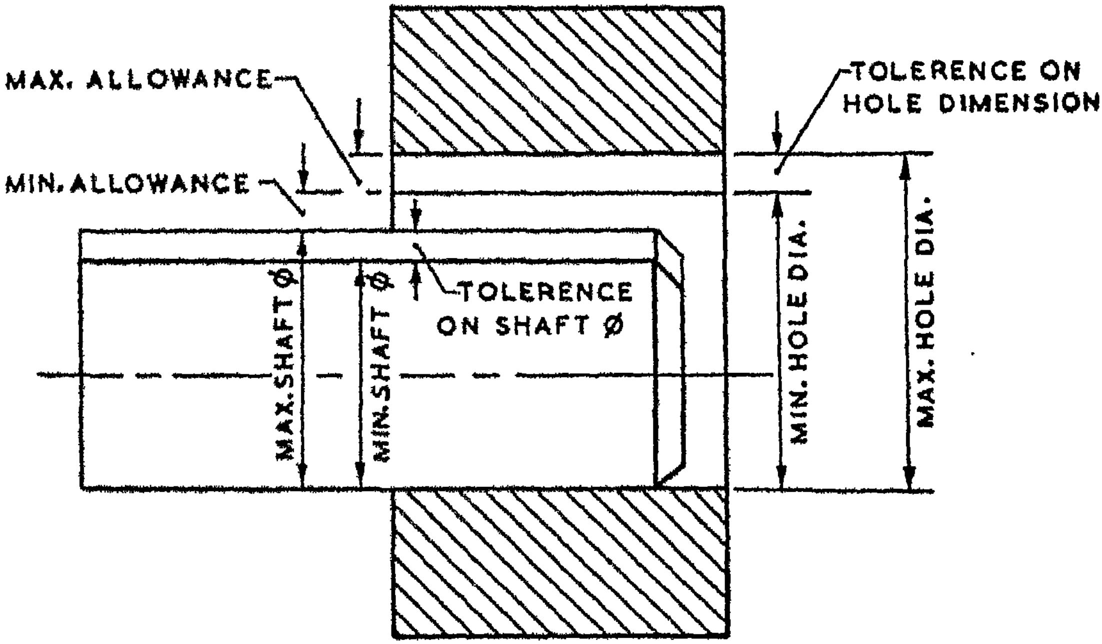


Fig. 5.26 Definition of tolerance and allowance

(1) *Clearance fit* is used for easy running of one part in another. In this case the minimum dimension of the hole is greater than the maximum dimension of the shaft ; or the allowance between them is positive.

(2) *Interference fit* results when the minimum diameter of the hole is smaller than the minimum diameter of the shaft ; or the allowance is negative. In this case the fit is called a *force fit* since a force is required to be applied to drive the shaft into the hole.

(3) *Transition fit* is obtained when the minimum size of the hole is smaller than the maximum size of the shaft, while the maximum size of the hole is greater than the minimum size of the shaft. The former gives an interference fit and the latter gives a clearance fit.

5.11 Pencil and Ink Tracings

Sometimes duplicate copies of the original drawings are required. In such cases, pencil or ink tracings of the original drawings are made. Pencil tracings must be made with dark dense lines without deep grooving of the paper or tracing cloth.

For more important drawings, the original pencil drawings are traced in ink or tracing cloth, or on good tracing paper. Since ink lines are wider than pencil lines, the ink lines should be carefully centred over the original lines.

The order of inking is important for obtaining a good ink tracing. The following order is recommended :

1. Centre lines.
2. Mark centres of all arcs and circles ; and mark the tangent points.
3. Full circles and arcs (smallest first).
4. Hidden circles and arcs (smallest first).
5. Irregular curves.
6. Full straight lines (horizontal first, vertical second, and inclined third).
7. Hidden straight lines.
8. Extension and dimension lines.
9. Section lines.
10. Arrowheads and dimension figures.
11. Lettering, notes and titles (use pencil guide lines).
12. Border.

PROBLEMS

1. What are multiview drawings ?
2. What are the main types of projection ?
3. What is the difference between perspective projection and parallel projection ?
4. What are the other names for perspective projection ?
5. What is the difference between projector and projection ?
6. What is the difference between parallel projection and orthogonal projection ?
7. How many views are necessary in order to completely define any object?
8. What is an axonometric projection ?

9. What is another name for axonometric projection?
10. What is the name of the most common type of axonometric projection?
11. Name the three principal planes of projection.
12. What do you call the intersecting lines of the three principal planes of projection?
13. How may solid angles do the three principal planes of projection make ?
14. What are the advantages of the third angle projection over the first angle projection ?
15. What is the recommended projection by the Indian Standards Institution—first angle or third angle projection?
16. What is the difference between an inclined line and an oblique line ?
17. What are traces of a plane ?
18. What is a dihedral angle ?
19. Define a surface, a ruled surface, a warped surface and a surface of revolution.
20. What are the basic principles of orthographic projection?
21. Assuming the three principal planes of projection opened out according to convention so as to coincide with the frontal plane, draw the projection of the following points:
    (*a*) 5 cm. behind the FP., 4 cm. below the H.P. and 6 cm. to the left of the P.P.
    (*b*) 5 cm. in front of the F.P., 4 cm. above the H.P. and 6 cm. to the right of the P.P.
22. Assuming x-axis to the left, y-axis vertically up, z-axis pointing away from the observer as positive directions draw, the projections of the three points: A (2, 3, 5), B (3, 6, 6) and C (6, 2, 1).

    Assume 1 unit = 1 cm. Find the true lengths of the lines A B, A C, and B C (i) by the method of projections and (2) by calculation. Draw the true shape of the triangle A B C.
23. Draw (i) a sectional elevation (ii) half sectional elevation (iii) a broken-out section of a church bell or a football or an ink-pot.
24. What are the principles of hatching ? How do you hatch if there are more than two adjacent parts ?
25. Draw the elevation of a cricket bat and show its sections as revolved sections.
26. Draw the elevation of a cricket bat and show its sections as removed sections.
27. State the parts which are not to be shown in section, although the section plane may cut them.

28. What are aligned sections ?
29. When do you require an auxiliary view ?
30. What is the method of revolution ?
31. What are working drawings ?
32. What are assembly drawings?
33. Define tolerance, allowance and fit.
34. State the principles of dimensioning.
35. Where do you use notes and titles on drawings and what is their purpose ?
36. What is the order of inking on a drawing ?

CHAPTER 6

Geometry of Solids and Planes

6.1 Simple Solids like Prisms, Pyramids, Cylinders and Cones

DEFINITIONS :

A *solid* is any quantity of matter that has a definite shape (or form). A geometrical solid is only the figure (or form) of any such solid.

A *polyhedron* is a solid bounded by plane surfaces. A *regular* polyhedron has for its faces (or sides) equal and regular polygons and the dihedral angle is the same between any two adjacent faces. There are only five regular polyhedra (plural of polyhedron), namely, the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron.

A *tetrahedron* is a solid contained by four equal equilateral triangles.

A *cube* is a solid contained by six equal squares.

A *octahedron* is a solid contained by eight equal equilateral triangles.

A *dodecahedron* is contained by twelve equal regular pentagons.

An *icosahedron* is contained by twenty equal equilateral triangles.

A *prism* has for its two ends, two equal, similar and parallel polygons and its sides are parallelograms. If the end polygons are also parallelograms, the solid is known as a *parallelopiped.*

A *pyramid* is a solid whose base (end) is a polygon and sides are triangles which meet in a common point known as the *vertex* or *apex* of the pyramid.

A *cylinder* is a solid whose ends are similar, equal and parallel closed curves and side is generated by a straight line moving parallel to itself along the end curves. The most common cylinder has circular ends and it can be generated by the revolution of a rectangle about one of its sides.

A *cone* is a solid generated by a straight line passing through a fixed point and intersecting some closed curve in space. The most common cone is generated by the revolution of a right angled triangle about one of its perpendicular sides.

The *axis* of a solid is the line joining the centres of its ends. If the axis is perpendicular to the base or ends, the solid is termed a *right* prism, pyramid, cone or cylinder. If the axis is not perpendicular to the ends, the solid is said to be *oblique.* It is usual to assume that the axis is perpendicular to the ends unless otherwise specified.

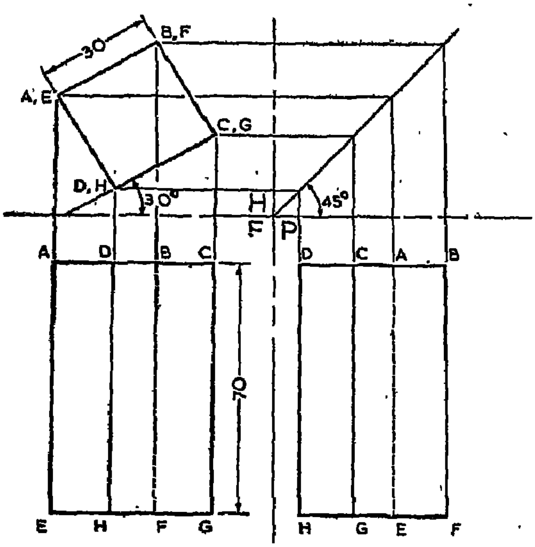
A *frustum* is a cone or pyramid whose upper part is cut off. It is also referred to as a *truncated* pyramid or cone.

The following worked-out problems illustrate multiview projections of some of the above solids. The student should follow them carefully and be able to do similar problems independently.

N.B. In the following, *the* H.P., *the* F.P. or *the* P.P. refers to *the* picture plane of the imaginary glass box, whereas, *a* H.P., *a* F.P., or *a* P.P. refers to any plane parallel to the corresponding plane of projection of the glass box. Only third angle projection is used.

Example 1 (Fig. 6.1)

To draw the front, top and profile views of a square prism when one end is on a H.P., and one side of that end is inclined at 30° to the F.P. The side of the base is 30 mm. long and altitude of the prism is 70 mm.



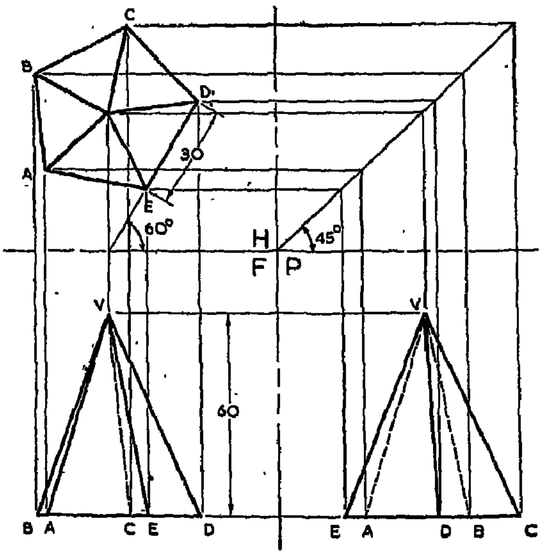
ALL DIMENSIONS IN mm

Fig. 6.1 Example—square prism

Assume the folding lines FH and FP. First draw the top view of the prism which is a square with one side inclined at 30° to the FH line. Draw projectors from the corners of the square, perpendicular to the FH line. The front view is drawn on these projectors making the altitude of the solid 70 mm. The right profile view is drawn similarly by drawing projectors perpendicular to the FP line and noting that the perpendicular distance of every point of the solid from the FP line must be the same as its perpendicular distance in the top view from the FH line.

Example 2 (Fig. 6.2)

To draw the front, top and profile views of a pentagonal pyramid of altitude 60 mm. and side of base 30 mm. when the base is horizontal and one of the sides of the base makes an angle of 60° with the FH line.



ALL DIMENSIONS IN mm

Fig. 6.2 Example—pentagonal pyramid

First draw the top view so that one side FD of the base makes an angle of

60° with the FH line. From the corners of the top view draw perpendicular to the FH line. Choose the base line BACED parallel to the FH line. Mark out the altitude and locate vertex in the front view. The profile view is drawn on the projectors from the front view perpendicular to the FP line. The corner points of the solid in the profile view are located on these projectors so that their distances from the FP line are the same as those in the top view from the FH line.

Example 3 (Fig. 6.3)

To draw the front, top and profile views of a cylinder whose altitude is 60 mm. and base diameter is 30 mm. when its axis is horizontal and inclined at 30° to the FP.

First draw the top view so that the axis is inclined at 30° to the FH line. Construct a semi-circle on DB and divide it into six equal arcs as shown. From these points draw perpendiculars to DB or LK. These lines give the front view

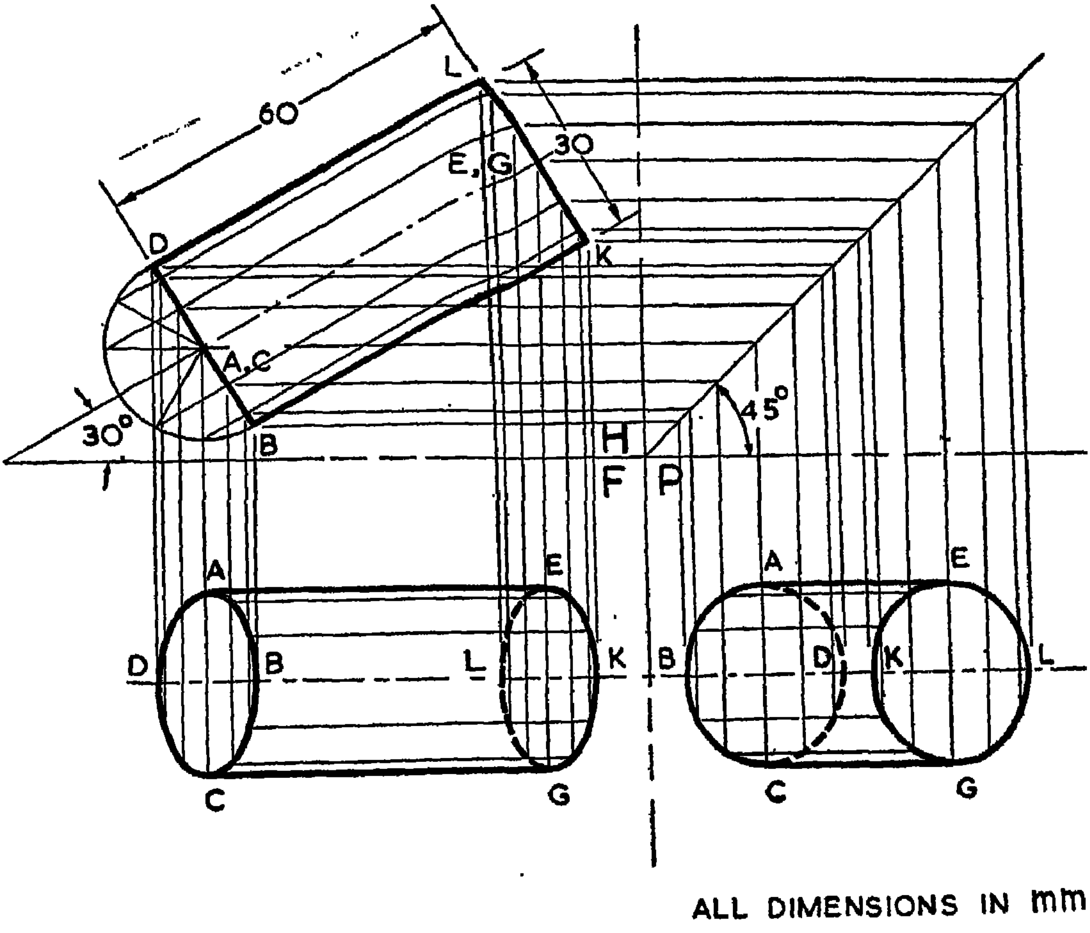


Fig. 6.3 Example—cylinder

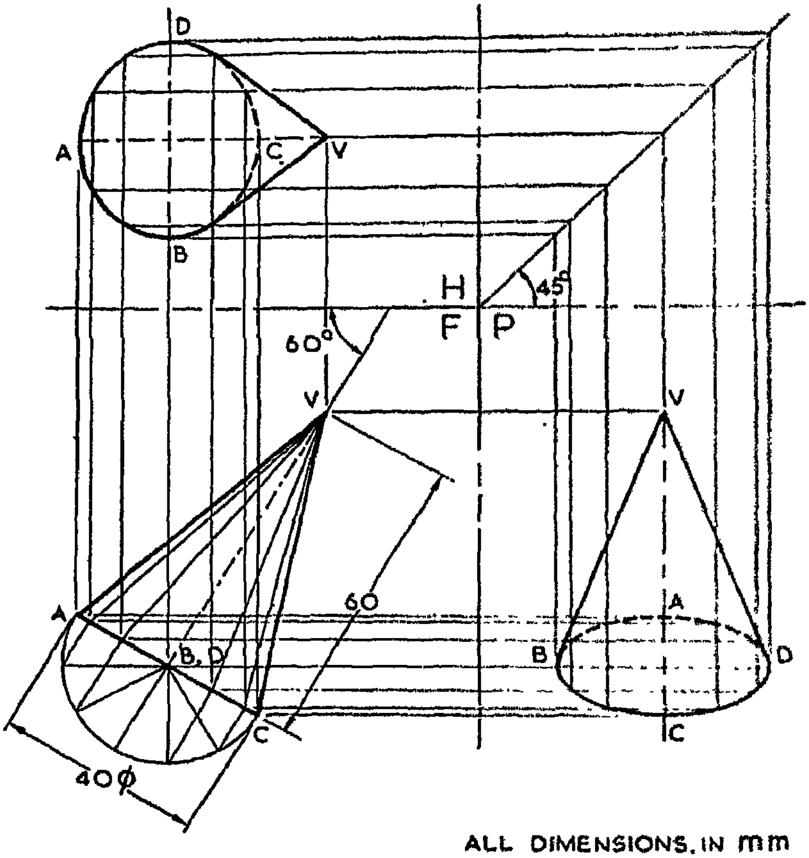


Fig. 6.4 Example—cone

of twelve straight elements on the surface of the cylinder. Of these twelve elements only seven are visible in the F-view. The other five are hidden and coincide with the visible elements. The curve in the F-view and in the P-view are found by projecting these line elements and then joining the end points of these elements by smooth curves.

Example 4 (Fig. 6.4)

To draw the front, top and profile views of a right circular cone whose altitude is 60 mm. and base diameter 40 mm. when its axis is parallel to the F.P. and inclined at 60° to the H.P.

First, draw the front view of the cone so that its axis makes an angle of 60° with the F. H. line. Locate, by the semi-circle construction, the twelve straight line elements of the surface, as in the previous example. Project these line elements on the H.P. and the P.P. Draw smooth curves through the end points of the line elements in the H-view and the P-view.

6.2 Intersection of Simple Solids with Planes

The intersection of any two surfaces gives a *line* (or *curve*) *of intersection*. The points of the curve of intersection are common to both the intersecting surfaces. This curve is found by determining a number of points common to both surfaces and drawing a line through these points in the correct order.

6.3 Surface Development

Only surfaces of polyhedra and singly-curved surfaces are developable; i.e., the surface may be laid flat on a plane. Practical applications of intersections and development of surfaces commonly occur in sheet metal work. The following examples illustrate the methods of obtaining the curves of intersection and development of surfaces.

Example 1 (Fig. 6.5)

The top and front views of a square prism are given as shown in the figure. A plane perpendicular to the F.P. and inclined at 60° to the H.P. passes through the centre of the top end of the prism. Draw the top view of the line of intersection and the true view of the section and also the development of the larger part of the solid.

First draw the cutting plane line 1-1 passing through the centre of the top of the prism and making an angle of 60° with the FH line in the front view. This plane cuts the prism at M, N, P and Q, in the front view. The top view of these points is obtained by projection as shown. The polygon M N P Q is the top view of the required intersection. Choose an auxiliary plane folding line FA parallel to the cutting plane. Draw the projectors from the points, M, N, P and Q perpendicular to the FA line. On these projectors locate the auxiliary view of the points M, N, P and Q so that their distances from the FA line are the same as their respective distances in the top view from the FH line. This polygon M N P Q on the auxiliary plane is the true view of the required line of intersection.

The development of the surface of the larger part of the prism is obtained as described in the following. Draw the four rectangular sides of the prism A B G E, B C L G, C D K L and D A E K opened out and laid flat as shown. Mark off the true distances A M, B N, B P, A M and D Q on the edges A E, B G, B C, A E and D A respectively. Join M N, N P, and Q M. The figure in thick line is the development of the sides of the larger part of the prism. The development of the top surfaces are the true views M N P Q and P C D Q. Lastly, the development of the bottom of the prism is simply the square E G L K shown in the top view.

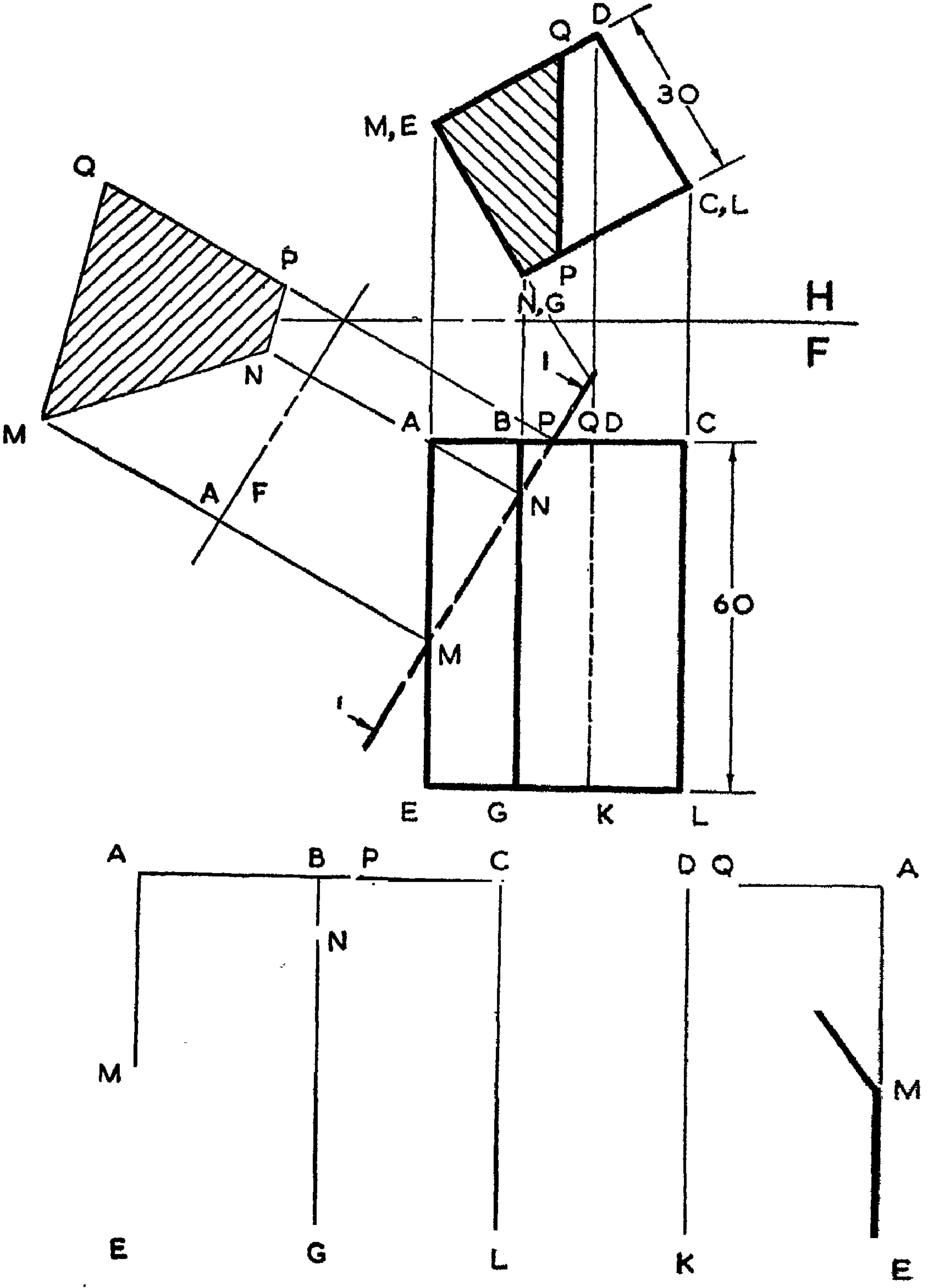
Example 2 (Fig. 6.6)

Draw the top view of the line of intersection between the cutting plane and the cylinder shown in the front view. Draw also the development of the larger part of the solid.

Top view of the cylinder is also a rectangle A C L G. The profile view is a circle G K L J. Let MN be a line element on the surface of the cylinder which is intersected by the cutting plane at point Q in the front view. In the profile view, the three points N, Q and M coincide. The top view of Q is located on the vertical projector by making its distance from the FH line same as its distance in the profile view from the FP line. Similarly, we may locate the top view of any number of intersection points of the other elements. The curve joining these points gives the top view of the required intersection curve as shown.

The true view of the section is shown at (a) in the figure, on an auxiliary plane. A typical point Q is located on the projector from the F-view perpendicular to the FA line by making its distance from the FA line same as its distance in the profile view from the FP line.

The development of the side of the larger part of the cylinder is shown at (b) in the figure. This is done by drawing the rectangle with a base length equal to the circumference of the cylinder. The height of the rectangle is made equal to the altitude of the cylinder,



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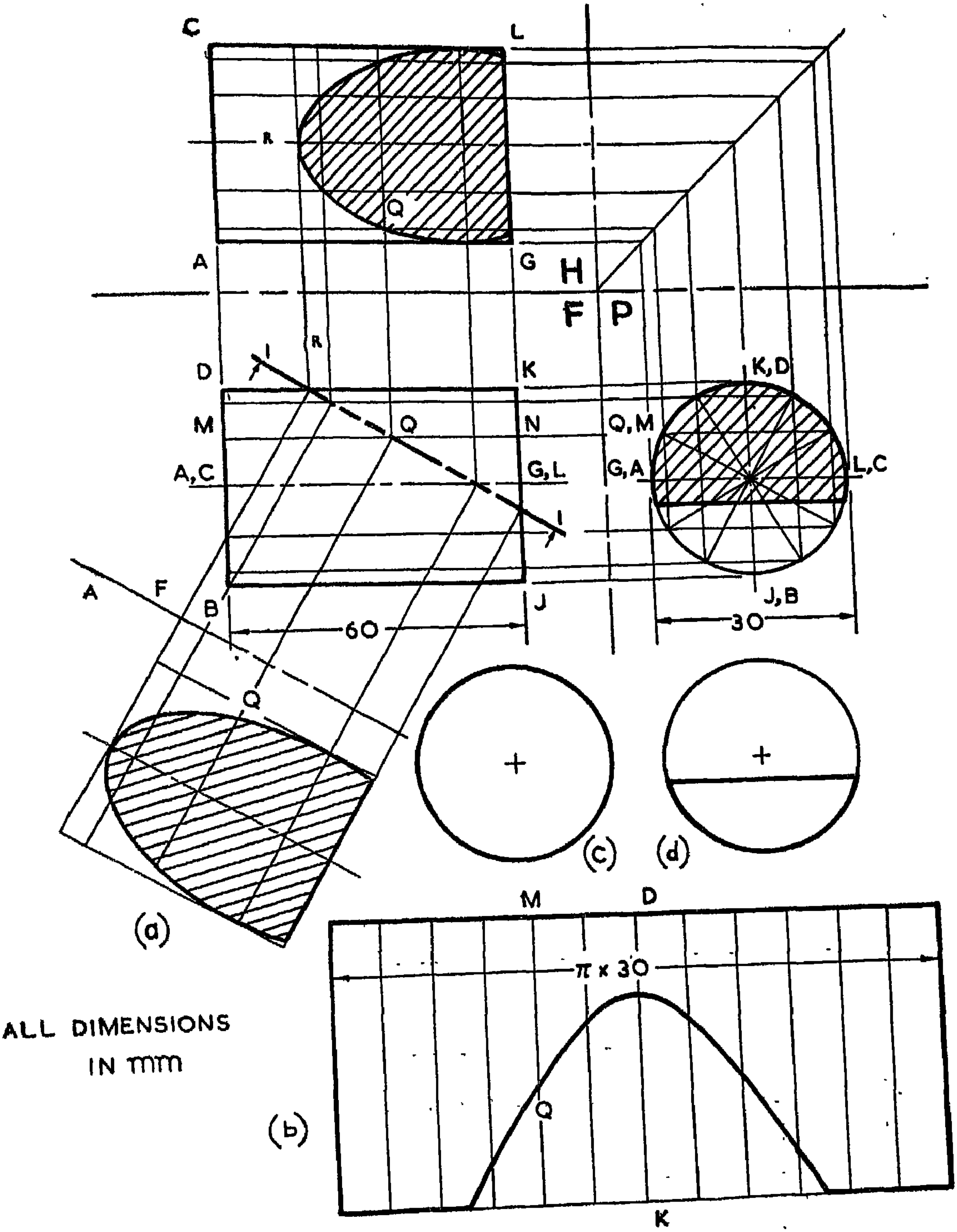


6,6 Example—intersection of a cylinder

Assume the element DK as the central element in this developed view. The point of intersection R is located on DK by marking out the distance DR as measured from the F-view. Any element such as MN is located in the development by stepping off the arc distance DM from the profile view, with the dividers. On the element MN the intersection point Q is located by marking the distance MQ from the F-view. Any number of intersection points may thus be located on the developed view. A smooth curve through these points gives the development of the line of intersection on the side. The larger part of the solid has also other plane surfaces as shown at (a), (c) and (d) in the figure. These require no further explanation.

Example 3 (*Fig. 6.7*).

Draw the top view of the line of intersection between the cutting plane and the cone shown in the front view of the figure. Draw the development of the frustum of the cone.

The top view of the cone is drawn first. Twelve straight line elements of the surface dividing the base into twelve equal parts are drawn in the plane and also in the F-view. The top view of a point of intersection such as Q, for instance, is located easily as the point where the vertical projector from Q on the element V6 in the F-view intersects the plan of the element V6. Other points of intersection are similarly located and a curve is drawn through them. This curve is the required top view of the line of intersection.

A true view of the section is obtained on an auxiliary plane parallel to the cutting plane as in previous problems. The auxiliary view is shown at (a) in the figure.

In order to obtain the development of the curved surface, with V as centre and radius equal to the sloping length of the cone draw an arc, Fig. 6.7(c). Make the arc length equal to the circumference of the base of the cone. Draw the elements of the cone 1 to 12 which divide the arc into twelve equal parts. On these elements mark off the true distances of the intersection points from the vertex V. For instance, the true distance of VQ in the F-view is VQ'. The curve joining these points is the development of the line of intersection. The required development of the curved surface of the frustum is shown in thick line in Fig. 6.7(c).

The development of the base is a simple circle Fig. 6.7(b), and the development of the top of the frustum is the auxiliary view shown in Fig. 6.7(a).

PROBLEMS

Note : All problems in this chapter are to be worked in third angle projection.

1. What is the difference between a solid and a geometrical soild ?
2. What is the difference between a prism and a parallelopiped ?
3. How many types of regular polyhedra are possible ? Name them.
4. What is the difference between tetrahedron and octahedron ?
5. What is the difference between a cone and a pyramid ?

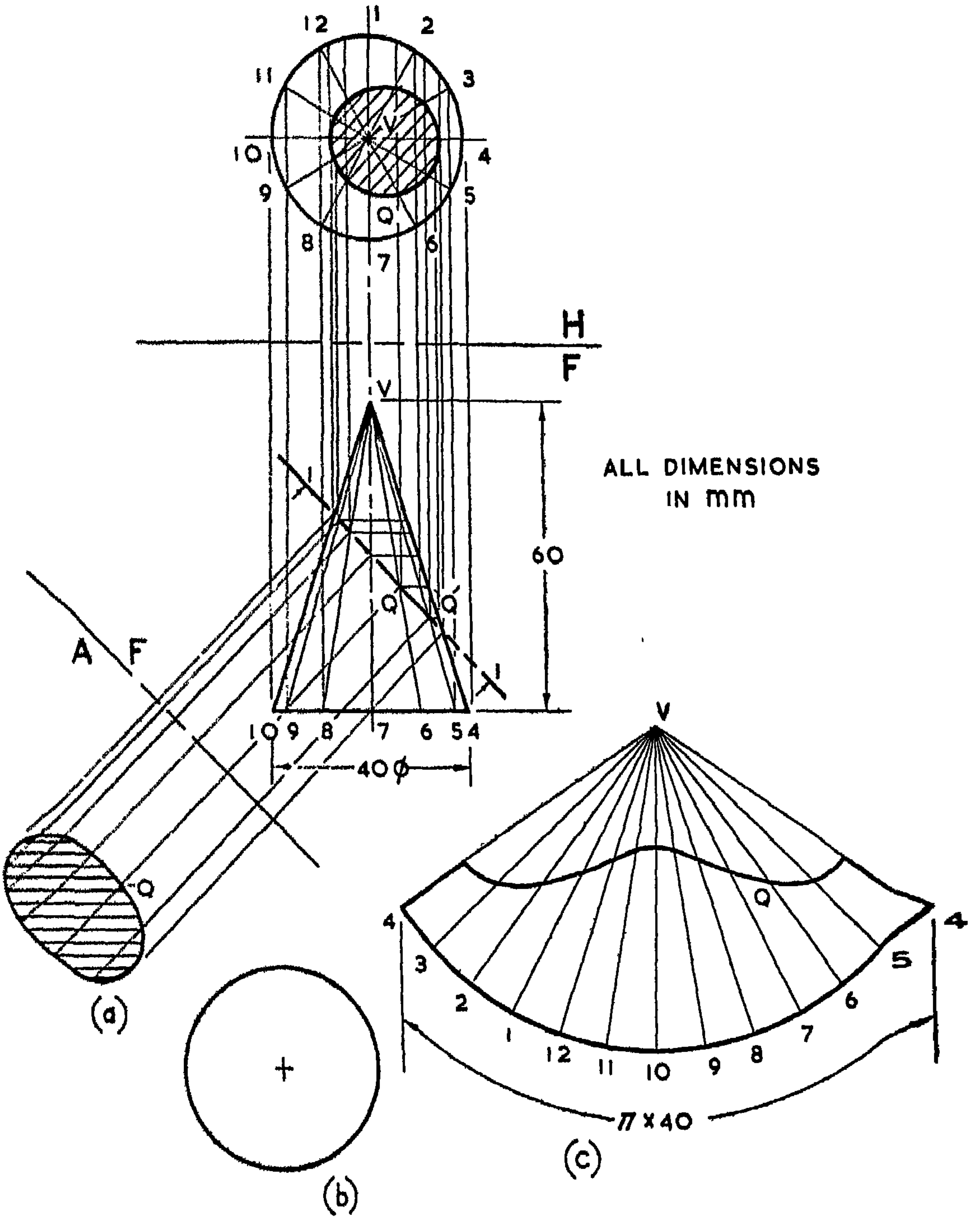


Fig. 6.7 Example—intersection of a cone

6. What is a frustum ?

7. Draw the front, top and profile views of a square prism with base 4 cm side, length 7 cm, when one end is touching the H.P. and one side of that end is inclined at 30° to the F.P. Show the folding lines.

8. Draw the top, front and profile views of a pentagonal prism, (a) when it lies with one face on a H.P. and its axis is perpendicular to the F.P. ; side of the pentagon 3 cm, length of prism 7 cm ; (b) when its axis is inclined at 30° to the F.P.

9. Draw the top, front and profile views of an oblique prism which has hexagonal ends of 3 cm side. The perpendicular from the centre of one end on to the plane of the other end passes through one of the angular points of the latter. The ends are horizontal and the plane of its axis makes 15° with the F.P. The altitude of the prism is 7 cm.

10. Draw the front, top and profile views of an oblique hexagonal pyramid whose base is parallel to the H.P. A perpendicular from the apex to the base passes through one of the angular points of the hexagon. The axis is parallel to the F.P ; side of the hexagon 3 cm, altitude of the pyramid 7 cm.

11. Draw the front and top views of a cylinder with base diameter 4 cm and length of axis 8 cm. The axis is horizontal and inclined to the F.P. at 30°.

12. Draw the front and top views of a right circular cone whose altitude is 7 cm and base diameter 4 cm, when its axis is horizontal and inclined to the F.P. at 60°.

13. Draw the front view of a square pyramid whose base side is 4 cm, and altitude 7 cm, when one side of the base makes an angle of 60° with the F.P. If a plane inclined to the H.P. at 45° bisects the axis, draw the plane of the frustum and also the true shape of the section.

14. Draw the development of the sloping sides of the frustum of the pyramid of the previous problem.

15. Draw the front view of a cone of base radius 3 cm and altitude 9 cm. A plane inclined at 30° to the H.P. and perpendicular to the F.P. cuts the axis at 4 cm from the apex. Determine the development of the frustum.

CHAPTER 7

Pictorial Drawings

7.1 Isometric Projection

A multiview orthographic projection shows the true size and shape of the faces of the object which are parallel to the planes of projection. However, it is not easy for an untrained person to visualise the shape of the object from such projections. A pictorial drawing of an object, on the other hand, helps any person to visualise the apparent shape of the object. Pictorial drawings are, therefore, commonly used in architectural drawings and trade catalogues to show what the buildings, machines or other objects, described therein, look like.

A pictorial drawing is one which represents an object as it appears to the observer. It may be a perspective drawing which is similar to a photograph of the object, or some other drawing which shows the three dimensions (height, width and depth) of the object in one view. A pictorial drawing has the disadvantage that it does not show the true shape and size of most parts of the object.

There are three main kinds of pictorial drawings :

(1) isometric projection, (2) oblique projection and (3) perspective projection.

An isometric projection is an axonometric projection or a uniplanar (or one-view) orthographic projection as described in article 5.2. It gives a three-dimensional pictorial view of the object. Consider a cube whose elevation is shown in Fig. 7.1a. If the cube is rotated and tilted so that the body diagonal AM (i.e. the diagonal through the centre of the solid) is perpendicular to the frontal plane, then the three edges AC, AB and AG make equal angles (35°16′ each) with the frontal plane. Its orthographic projection on the F-plane is shown in Fig. 7.1b. This projection is called an *isometric projection* of the cube. The edges of the cube in this position are

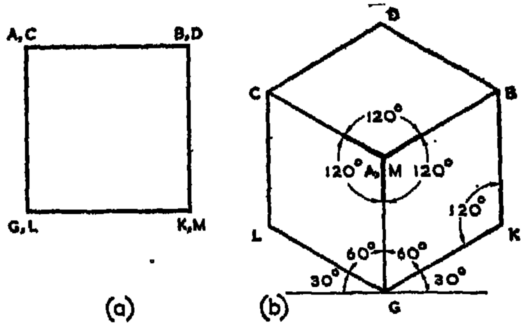


Fig. 7.1 Isometric projection of a cube

called the *isometric axes or isometric lines.* Since the edges are equally inclined to the plane of projection, they are foreshortened equally in the projected view. Hence the name "isometric" which means "equal measure". The projected length of each edge of the cube is $\sqrt{\frac{2}{3}}$ or 0.8165 times its true length. The three edges of the cube, at the corner nearest to the observer, appear to be 120° apart in the projected view, Fig. 7.1b. The other right angles of the cube appear to be either 60° or 120° in the projected view.

In order to represent the linear dimensions of the edges of the cube, in isometric projection, we must use a scale which reduces the true lengths by a constant factor equal to 0.8165. This scale is called the *isometric scale.* If a full scale is used (instead of the isometric scale) to represent the dimensions of the isometric lines, the resulting drawing is called an *isometric drawing* instead of an *isometric projection.* Since the use of an isometric scale is not very convenient, it is common practice to use the isometric drawing instead of the true isometric projection.

It is important to note that all measurements must be made only on isometric lines or on lines parallel to them. Straight lines that are not parallel to the isometric lines are called *non-isometric lines.* No measurements must be made on these lines, since the ratio between the projection and the true length of such a line is not constant. Such lines can be drawn in the isometric projection (or drawing) by locating their end points on isometric lines.

Circles and curves in isometric projection (or drawing) may be drawn by locating several points of the curves on isometric lines and then drawing a smooth curve through them. The following examples will explain the procedure.

Example 1

To Construct an Isometric Scale

The ratio of the isometric scale to the true scale is $\sqrt{\frac{2}{3}}$. Let OA, OB, and OC be the projections of three equal lines meeting at O, which are mutually perpendicular, and make equal angles with the plane of projection. The projections OA, OB and OC are 120° apart, Fig. 7.2a. Join AB. On AB describe a semi-circle which cuts OC at D. Join AD. It is evident from the construction that angle DAE = 45° = angle ADE, and angle OAE = 30°. Hence AD = $\sqrt{2}$ AE, and OA = $\frac{2}{\sqrt{3}}$ AE. Or, OA $\sqrt{\frac{2}{3}}$ AD. Hence, if AD represents the true scale, OA will represent the isometric scale. The scale AD may be divided into as many divisions as necessary. The corresponding division points on the isometric scale AO may be found by drawing parallels to OD from the division points on AD as shown in Fig. 7.2b.

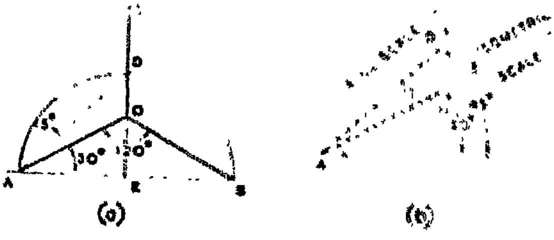


Fig. 7.2 Isometric scale

Example 2

The top and front views of a wedge are given in Fig. 7.3a. Draw an isometric drawing of the object. All dimensions shown on the drawing are in millimetres.

The wedge is enclosed in an imaginary rectangular prism with its top face C'A' GE as shown in Fig. 7.3b. First draw the isometric view of the rectangular prism as shown. AB and CD are non-isometric lines. Locate the end points A,B,C, and D of these lines on the isometric lines AL, BG, CK and DE using the dimensions shown in Fig. 7.3a. Draw the lines AB, BD, DC and CA. The final isometric drawing of the wedge is shown in thick line, Fig. 7.3b.

Example 3

A cube of 40 mm. edge has inscribed circles on each face. Make an isometric drawing of the cube.

First draw a square of 40 mm. side and draw the inscribed circle, Fig. 7.4a. On this circle mark any number of points such as A, b, c, d and e and draw vertical lines through these points to meet the edges of the square at A, B, C, D and E. Draw the isometric view of the faces of the cube and of the vertical lines corresponding to AA, BB, CC, DD and EE, Fig. 7.4a. On these vertical lines mark off the vertical distances Bb, Cc, Dd and Ee as measured in Fig. 7.4a. A smooth curve through the points A, b, c, d and e gives the isometric drawing of the circle, Fig. 7.4b. A similar procedure is used for drawing the isometric view of the circle on the other faces of the cube.

7.2 Oblique Drawing

Oblique drawing (also called oblique projection) is another form of uniplanar pictorial drawing. In this type of drawing, similar to isometric drawing, the object is assumed to be basically a rectangular prism. Unlike orthographic projection in oblique drawing, the projectors are oblique to the picture plane instead of being at right angles to it. The projectors are parallel to each other and may be inclined at any angle to the picture plane. But these are generally assumed to make an angle of 45° with the picture plane.

In oblique projection, the principal face of the prism, Fig. 7.5a, is always placed parallel to the picture plane. Hence, its projection is true in shape and size. This makes oblique drawing simpler than isometric drawing. Circles and irregular curves parallel to the principal face of the object may be shown in their true shape. This is a great advantage over isometric drawing. But the projections of the faces perpendicular to the principal face are not true in shape. The projected length of the lines parallel to the OZ axis of the object, Fig. 7.5a, are, however, true in length, since the projectors are inclined at 45° to the picture plane. The axis OZ of the object perpendicular to the principal face is called the *receding axis*. In oblique drawing the projection of the receding axis may be chosen at *any angle*, with the projection of the OX axis. For convenience the angle is generally chosen as 45°. The three mutually perpendicular axes OX, OY and OZ of the prism are known as the principal axes, Fig. 7.5(a).

The two main types of oblique drawing are : (1) *cavalier* projection and (2) *cabinet* projection.

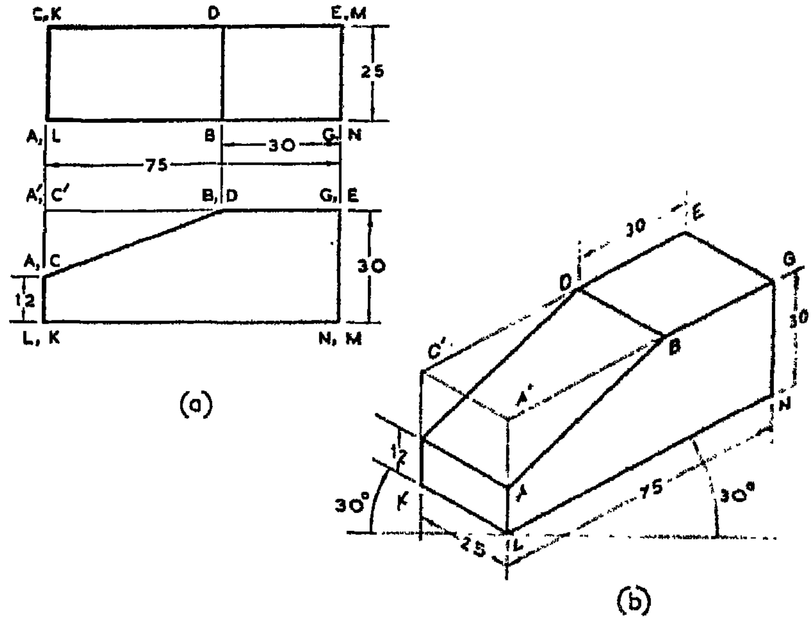


Fig. 7.3 Isometric drawing of a wedge

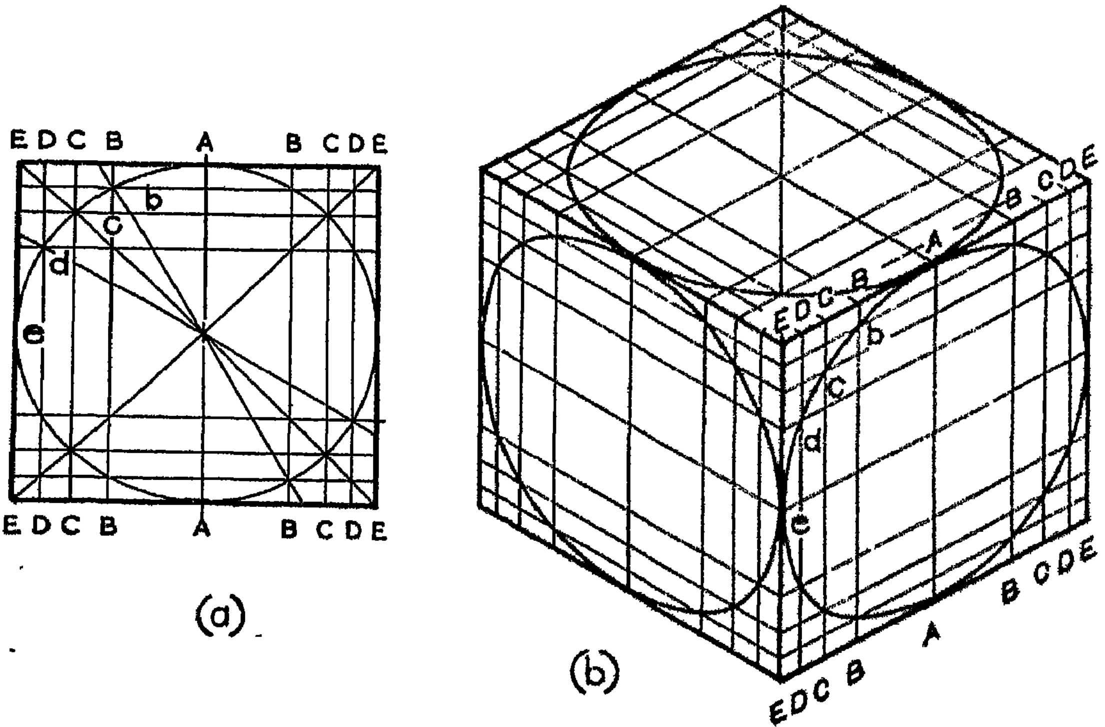


Fig. 7.4 Isometric drawing of a cube

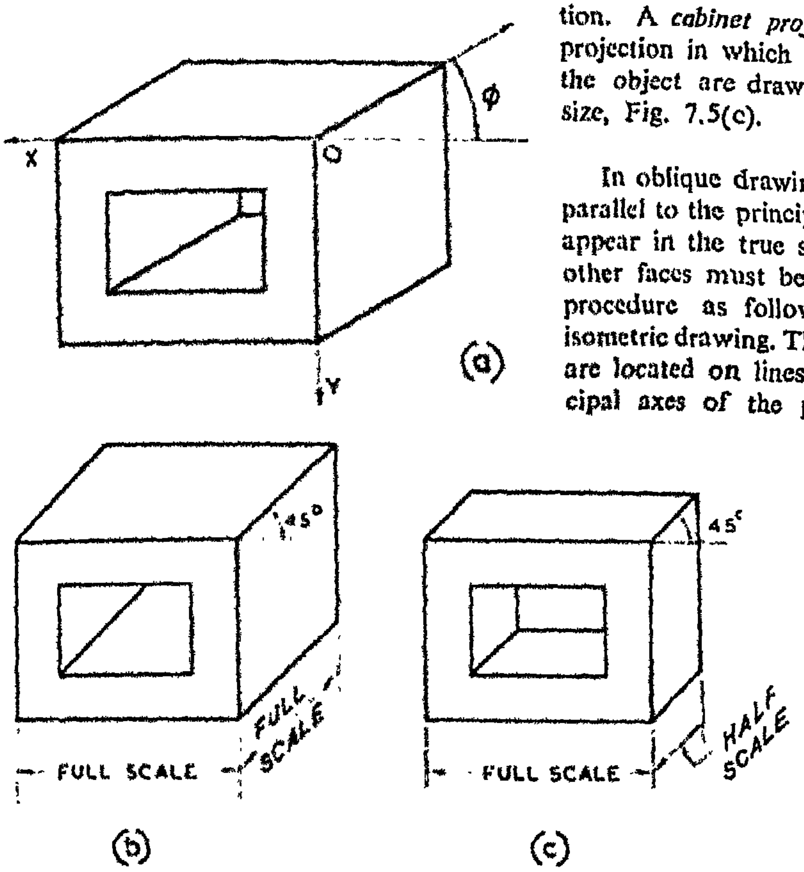


Fig. 7.5 Oblique, cavalier and cabinet projections

The oblique drawing described above, in which the projectors make an angle of 45° with the plane of projection is called a *cavalier projection*, Fig. 7.5(b). In cavalier projection, the lines parallel to the receding axis appear in their true lengths. But the view of the object appears to be distorted and unnatural. This is because, the eye is accustomed to see all receding parallel lines as converging to a point, whereas, these lines in a cavalier projection are parallel and not converging.

The distorted appearance of the object referred to above may be improved by decreasing the length of the receding lines. This is done in a cabinet projection. A *cabinet projection* is an oblique projection in which the receding lines of the object are drawn to half their full size, Fig. 7.5(c).

In oblique drawing, circles and curves parallel to the principal face of the object appear in the true shape. But those on other faces must be drawn by the same procedure as followed in the case of isometric drawing. The points of the curves are located on lines parallel to the principal axes of the prism and a smooth curve is drawn through these points.

It is important to remember that in oblique or isometric drawing all measurements must be made only on lines parallel to the principal axes.

7.3 Perspective Drawing

A photograph of an object is a perspective view of the object. A perspective view (or projection) shows an object as it would appear to the eye of an observer. Perspective drawings are generally made by architects and artists. The shape of an object is generally distorted in a perspective projection. The *apparent shape* of a complicated object or assembly is, however, more easily understood by any person, from a perspective drawing than from an orthographic projection. For this reason, the use of perspective drawings is growing in importance in the aircraft and automobile industries to show what their new car or aeroplane would look like.

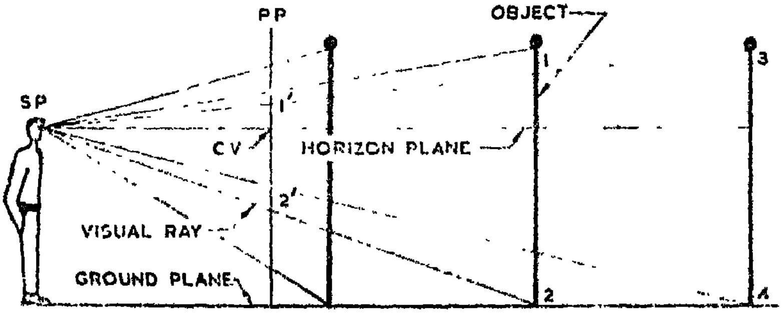


Fig. 7.6 Perspective projection—definitions

The observer, in Fig. 7.6, is standing in the middle of a straight road which has lamp-posts on both sides of the road. He is looking through an imaginary vertical transparent plane. This plane on which the projection is made is called the *picture plane*, or *PP*. The PP is usually placed between the object and the observer. The position of the eye of the observer relative to the PP is called the *station point*, or SP. The lines drawn from the SP to the various points of the object are called *projectors, line of sight* or *visual rays*. The points where the projectors *pierce* the PP are said to be the perspectives of the object points. These perspective points form the perspective view (or projection) of the object. For instance, the perspective of the lamp-post, Fig. 1-2, is represented by 1'-2' on the PP. The horizontal plane passing through the eye of the observer (SP) is the *horizon plane*. The *horizon line* is the line of intersection of the picture plane and the horizon plane. The *ground line* is the line of intersection of the picture plane with the ground plane. The ground plane is also assumed to be horizontal. The *centre of vision*, or CV, is the foot of the perpendicular from SP on the picture plane. In other words. CV is the orthographic projection of SP on the PP. Thus CV is directly in front of the eye on the horizon line. The visual rays form a cone of vision with the SP as its vertex. The line joining the points SP and CV is called *the axis* of the cone of vision. In order to have a good perspective view, the angle of the cone of vision at its vertex (SP) should not exceed 30°. The plane perpendicular to the ground plane and containing the SP and CV is called the *vertical plane*. The line of intersection of the vertical plane and the PP is called the *vertical line* or *the vertical axis*.

The perspective projection on the PP seen by the observer in Fig. 7.6 is shown in Fig. 7.7. It is important to note the following facts regarding the one-point and two-point perspective projections.

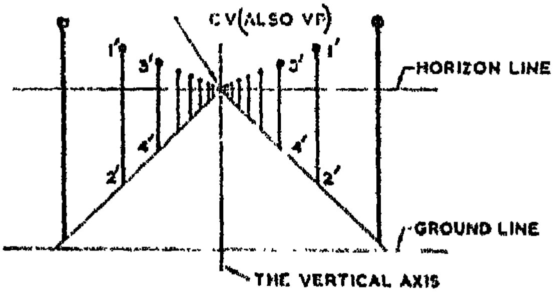


Fig. 7.7 One-point perspective projection

1. The perspectives of parallel lines of the object, *not parallel to the PP*, converge to a point on the PP. This point is called the *vanish-*

ing point, or VP, of the parallel lines is the point where a line parallel to the sytem passing through the SP pierces the picture plane.

2. The VP of parallel horizontal lines (not parallel to the PP) lies on the horizontal line.
3. The perspectives of horizontal parallel lines perpendicular to the PP converge to a VP which coincides with the CV.
4. The perspectives of all vertical lines, like the lamp-posts in Fig. 7.7, remain vertical.
5. The perspectives of all lines parallel to the PP are parallel.
6. The perspectives of all horizontal lines which are parallel to the PP are parallel to the horizon line.
7. The perspectives of parallel lines which are parallel to the vertical plane converge towards a VP on the vertical axis.
8. The perspective of a line coinciding with the PP shows its true length.
9. The perspective of a line behind the PP is shorter than its true length.

Types of Perspectives: There are three types of perspectives according to the number of vanishing points required in drawing the perspective. These are known as (1) one-point perspective, (2) two-point perspective, and (3) three-point perspective. One-point perspective is alternatively called *parallel perspective*. The two-point and three-point perspectives are also known as *angular perspectives*. As for other pictorial drawings, in perspective drawing also, the object is considered to be basically a rectangular prism, with three principal axes mutually at right angles to each other.

One-point Perspective: In one-point perspective, the principal face of the object is placed parallel to the PP. The perspective of this face, therefore, is true in shape. It will be true in size also if the face of the object is made to coincide with the PP. The perspective of the receding edges of the object perpendicular to the PP will converge to a VP (coinciding with CV) on the horizon line. One-point perspective has only one vanishing point. (e.g. Fig. 7.7.)

Two-point Perspective: A two-point perspective has two vanishing points. This kind of perspective is the one most commonly used. Small objects may be placed above, below or on the horizon line (which represents the level of the eye of the observer), Fig. 7.8. A two-point perspective is also called *angular perspective* because the principal face of the object makes some angle with the PP. This angle is usually taken as 30° for convenience. The other adjacent face of the object will, therefore, make angle of 60° with the PP.

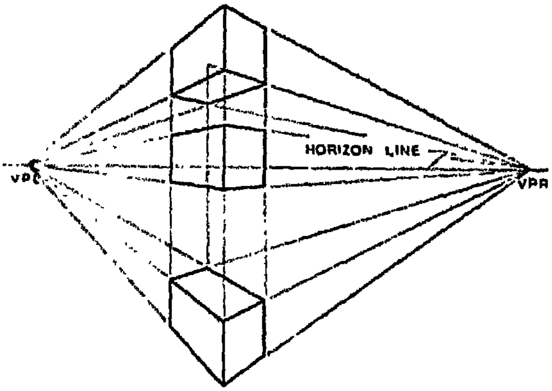


Fig. 7.8 Two-point perspective projection

The following example will explain the procedure of drawing the one-point and two-point perspectives.

Example

The length of a square prism is twice its width. The ends of the prism have circles inscribed on their faces. Draw (1) a one-point perspective and (2) a two-point perspective of the solid.

(1) *One-point perspective, Fig. 7.9*: Draw the top view of the solid and of the PP in orthographic projection. This is shown in the figure above the line PP. The end ABCD of the prism is chosen to coincide with the PP. Hence, its orthographic projection A′ B′ C′ D′ is its perspective. The edge C′D′ is made to coincide with the ground line. Draw the horizon line above the ground line at a height equal to the height of the eye level of the observer. This height is usually taken to be 1.6 mm. Locate SP_h,

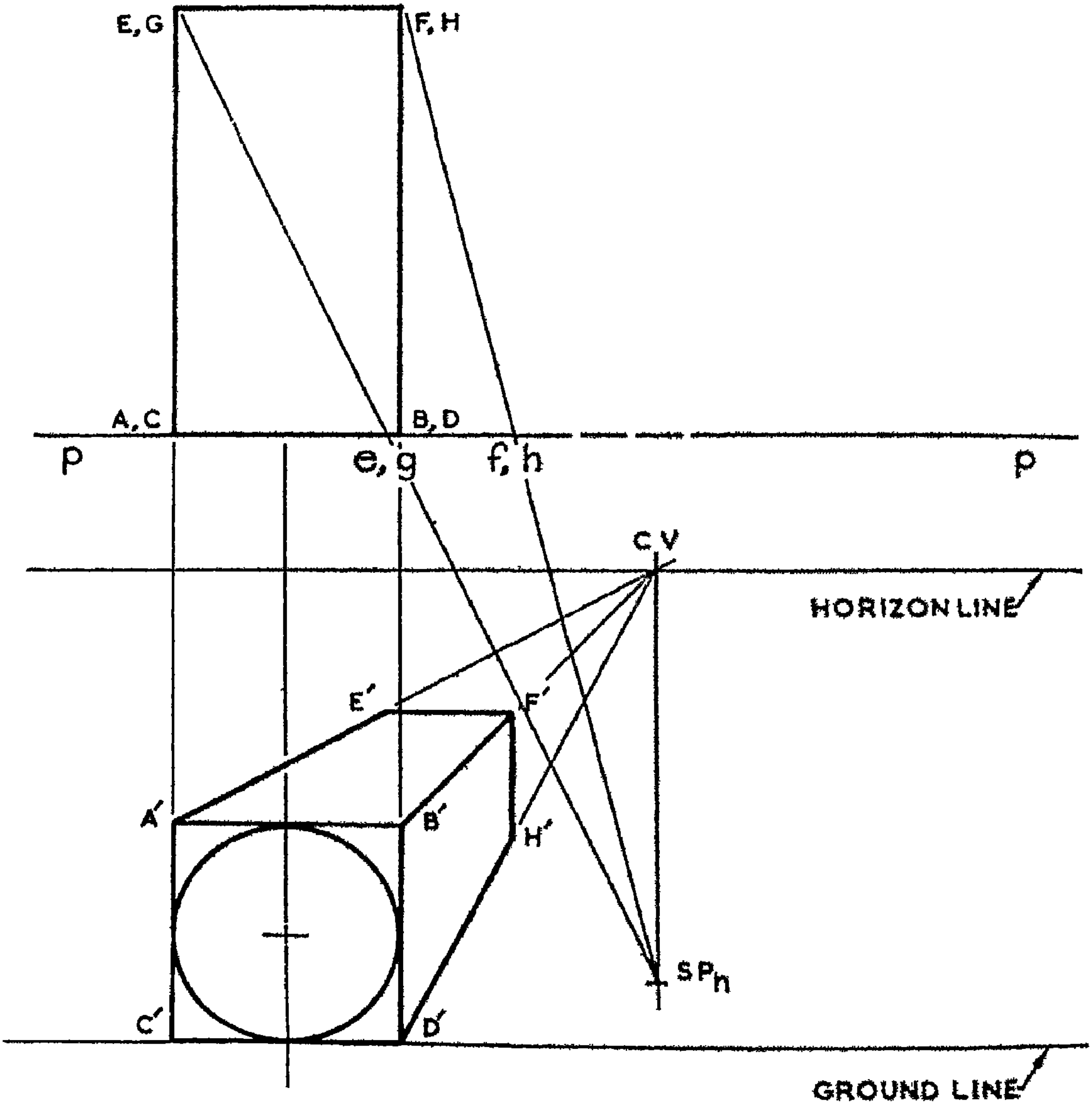


Fig. 7.9 Example—one-point perspective

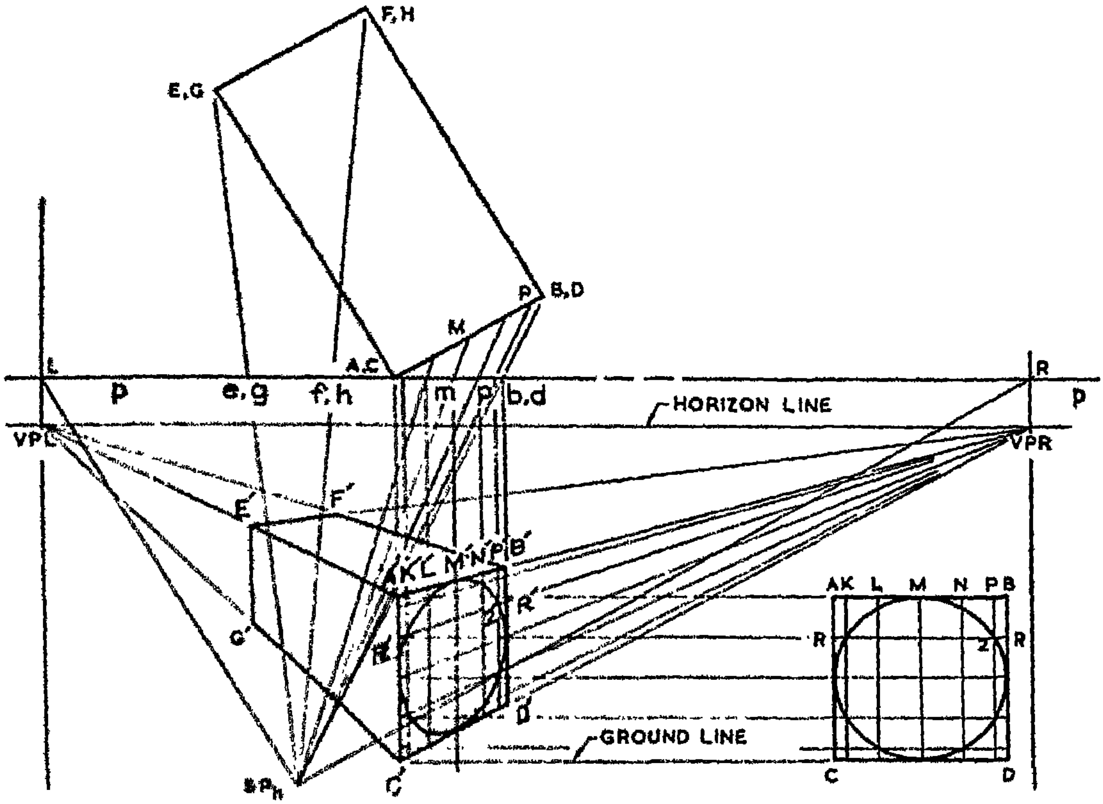


Fig. 7.10 Example—two-point perspective

the top view of SP, as shown in the figure. The orthographic projection of SP on PP is the point CV situated on the horizon line. Draw the projectors from SP$_H$ to the various corners of the object in the top view. Note carefully the piercing points in the top view. For instance, the projectors from SP$_H$ to the points E and F pierces the PP line at e and f. The whole space from the ground line to the PP line represents the picture plane or the frontal plane on which the perspective projection is made. The PP line is the folding line of the horizontal plane on which the top view is made in orthographic projection. *The perspective view of the object is nothing but the front view of the piercing points on the PP.* Join A', B', C' (and D' to CV). The receding edges of the object must be on these lines which vanish at CV.

To locate the perspective of a point such as E in the top view, draw a perpendicular to PP line from the corresponding piercing point e. This perpendicular intersects the corresponding receding line A'-CV at E'. The other corners of the object are similarly located. The perspective view of the solid is shown in thick line in Fig. 7.9.

(2) *Two-point Perspective, Fig. 7.10*: First draw the ground line, the horizon line and the PP line. The PP line represents the top view of the picture plane. In the space above the PP line, draw the top view of the object in orthographic projection as shown, so that the vertical

edge AC coincides with the PP and the end face ABCD makes an angle of 30° with the PP line. Select SP (the top view of SP) at a convenient position as shown. From SP_h draw projectors to all the corners of the object and locate the piercing points on the PP line.

The next step is to determine the left and right vanishing points (VPL and VPR) for the two systems of horizontal parallel lines of the object. From SP_h draw two lines parallel to these systems (i.e. parallel to AE and AB in the top view). These lines intersect the PP line at L and R. Project these points downward and mark the two points VPL and VPR on the horizon line. These are the perspectives of the two vanishing points. The perspective A'C' of the vertical edge AC lies in the PP. Hence, it is drawn standing vertically on the ground line showing its true length. The perspective of any corner such as E (in the top view) is found by drawing a perpendicular to the PP line at the corresponding piercing point e. This perpendicular intersects the line A-VPL at E'. E' is the perspective of E. Similarly, the perspectives of other corners of the prism are determined and the perspective of the prism is shown in thick line, in Fig. 7.10.

The perspective of the inscribed circle on the face ABCD is determined next. The circle and its enclosing square are shown standing on the ground line, in their true shape and size, near the lower right-hand corner of the drawing. The point of the circle such as 1,2,3,... are the intersection points of a grid of vertical and horizontal system of parallel lines, on the face ABCD. The top view of the points K,L,M,N, and P of the grid are marked off on the edge AB. Draw projectors from SP_h to these points and locate their corresponding piercing points k,l,m,n and p on the PP line. A typical point 2 of the circle lies at the intersection of the vertical line through P and the horizontal line RR. The perspective point R' on A'C' is just the horizontal projection of R on A'C', since A'C', is seen in its true length. Join R' to VPR and locate the perspective R' R'. Draw a perpendicular to the PP line at the piercing point p. This perpendicular intersects the line A'B' at P' and also the line R'R' at 2'. 2' is the required perspective of the point 2. The perspectives of the other points of the circle on the end face are determined similarly. A smooth curve is drawn through these points as shown.

Three-point Perspective: For a one-point or two-point perspective, the PP is taken to be parallel to the vertical edges of the object. If PP is not parallel to any of the edges of the prism (or object) the perspectives of the three systems of parallel lines of the prism would have three vanishing points as shown in Fig. 7.11.

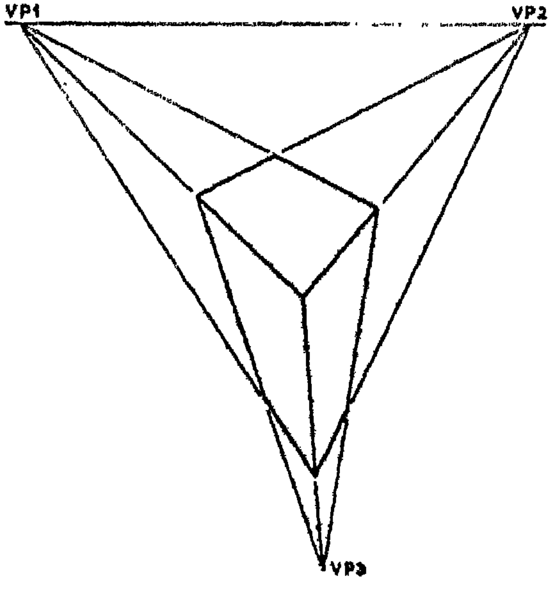


Fig. 7.11 Example—three-point perspective

A three-point perspective is rarely used, in practice. The principles of the three-point perspective may be studied in more advanced books (see reference Nos. 1 and 2 in Appendix III—Bibliography given at the end of the book).

PROBLEMS

1. What are the main types of pictorial drawings?
2. What is the difference between isometric projection and isometric drawing?
3. Describe with sketches how to construct an isometric scale.
4. What are isometric lines and non-isometric lines?
5. A cube of 6 cm. edge has inscribed circles on each face. Make an isometric drawing of the cube.
6. Make (i) a cabinet projection, and (ii) a cavalier projection of a cube of 5 cm, edge.
7. What is the difference between perspective projection and isometric projection?
8. What are the important facts to note in one-point and two-point perspective projection?
9. A square prism 4 cm. by 4 cm. by 8 cm. has inscribed circles on its ends. Draw (i) a one-point perspective and (ii) a two-point perspective of the prism.

CHAPTER 8

Machine Drawing

8.1 Freehand Sketching of Simple Machine Parts

Freehand sketching has an important place in engineering practice. A new design is first sketched and later drawn to scale. It is only by sketching several versions of a particular design that one can judge among them and choose the best or leave it to others to do that.

When it comes to explaining a modification of an existing machine or a part of it, a freehand sketch can do it much better than words. There are few things simpler than freehand sketching. The only accessories or tools required are a pencil, paper and an eraser. It is perhaps the only practicable way of conveying an idea of a machine detail in the quickest possible time and with some practice one can do it neatly enough.

Freehand sketches may be drawn in multiview projections. Alternatively, they may be drawn in a pictorial view, that is, the axonometric, oblique or perspective view. The length, breadth and depth or height are to be drawn first lightly in thin lines. Then the other details may be developed with reference to these axes. Graph papers or squared papers are found very helpful in this respect as they provide two sets of perpendicular lines which may be used as the two axes in question.

The lines in a freehand sketch need not be all of *uniform* quality. Important visible lines such as outlines should be thickly drawn whereas centre lines or dimension lines should be drawn very thin. Invisible details drawn in dotted lines should be given only when absolutely necessary.

Freehand sketches are not drawn to scale. But it is necessary that the sketches should be properly proportioned in order to get an idea of the overall shape. The actual size of the sketch depends on convenience.

For freehand sketching use a soft pencil of the order of HB or F and sharpen the point conically. For drawing very thin lines the fine point is useful. Otherwise it is better to have the point a little blunt.

8.2 Scale Drawings of Screws

Introduction: The screw is a very important feature of various machine elements. Its main functions are:

(a) to hold parts together,
(b) to adjust one part with reference to another, and
(c) to transmit power.

DEFINITIONS

The following terms are used frequently in connection with a screw and its workings (Fig. 8.1).

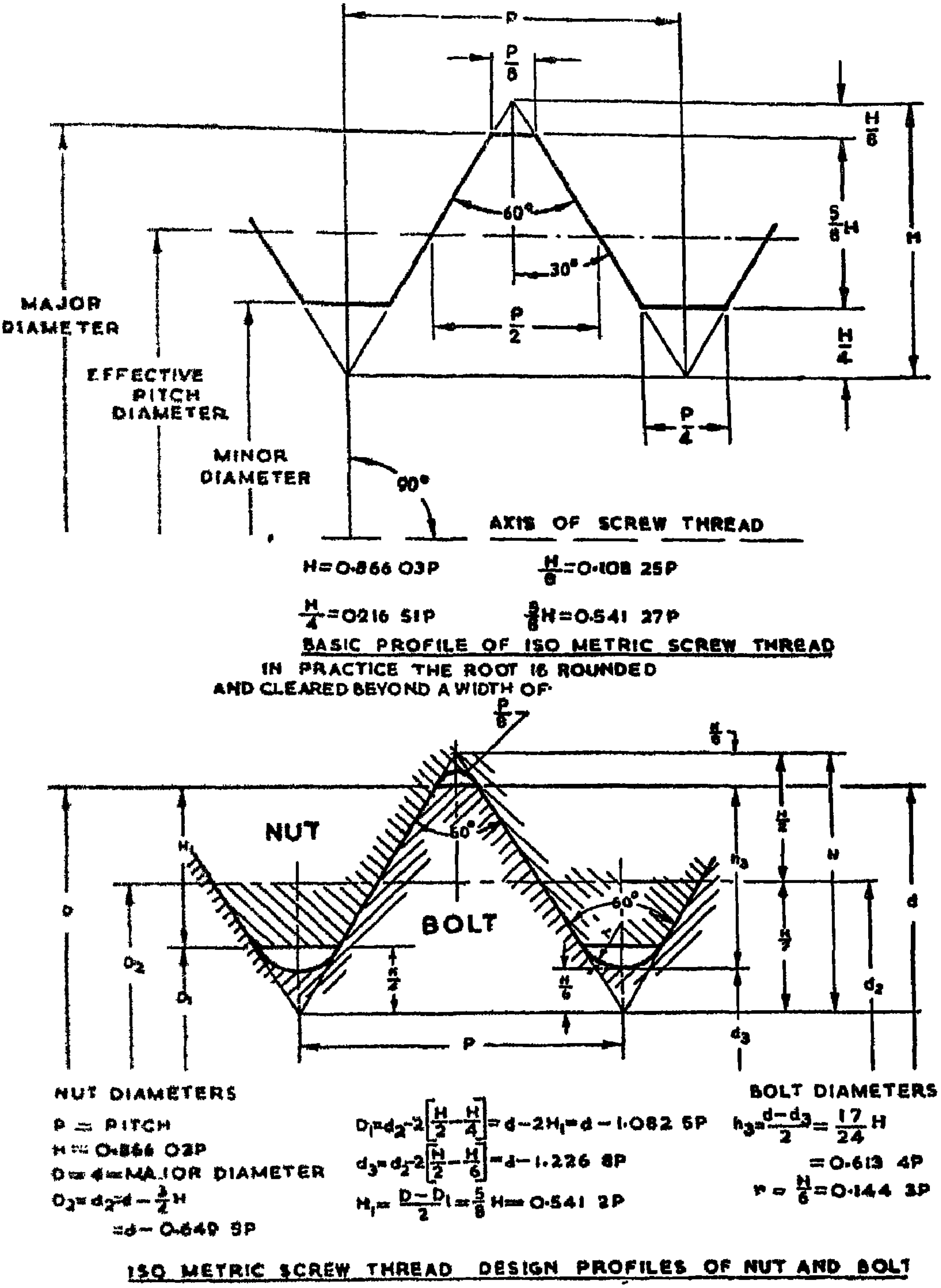


Fig. 8.1 Basic profile of isometric screw thread

Screw thread: The ridge produced by forming on the surface of a cylinder a continuous helical or spiral groove of uniform section, such that the distance measured parallel to the axis between two points on its contour is proportional to their relative angular displacement about the axis.

External screw thread: A screw formed on the outside surface of a cylinder. The screw thread on a bolt is an example of this. These threads are either cut on a lathe or are made by thread-cutting dies generally.

Internal screw thread: A screw formed on the inside surface of a hollow cylinder. The thread of a nut is an example of this. Such threads are usually cut by taps or can be cut on a lathe.

Pitch of a screw is the distance measured parallel to the axis between corresponding points on adjacent threads. In metric system this is usually expressed in millimetres. In F.P.S. system it is either expressed in inches or sometimes the threads are specified in T.P.I., that is, threads per inch. The pitch in inches is the reciprocal of T.P.I.

Lead of a screw is the axial distance moved by the screw for one complete revolution about the axis. For a single thread, pitch is equal to lead. For a multiple thread, which is composed of two or more threads running side by side, the lead is equal to pitch multiplied by the number of threads.

Right-hand and Left-hand threads: When a screw thread moves into a nut clockwise rotation, it is called a right-hand thread. A left-hand thread moves in a nut when turned counter-clockwise.

Major diameter is the largest diameter of a screw thread.

Minor diameter is the smallest diameter of a screw thread.

Pitch diameter or *Effective diameter* is the diameter between the major and minor diameters at which the width of the thread and the width of the gap are equal.

Crest is the top surface of a screw thread.

Root is the bottom surface of a screw thread.

Forms of screw threads: There are various forms of screw threads to meet the various requirements. Fig. 8.1 shows the thread forms of screws for general purpose for diameters from 0.25 mm. to 39 mm. as specified by the Indian Standards. A metric screw thread is designated as follows : An M 10 × 1.25 screw thread means a screw of 10 mm. diameter and 1.25 mm. pitch. This type of thread form is known as *V-thread.*

Two other common V-threads are (i) Unified V-thread, and (ii) Whitworth thread which is also commonly known as B.S.W. or British Standard Whitworth thread. It is used in inch units. Different thread forms are shown in Fig. 8.2. These are:

Square thread: used for power transmission purposes.

Acme thread: used also for the same purpose, but it is superior to square threads in strength and also easier to make.

Knuckle thread: used on sheet metals, bottle tops, etc.

Buttress thread: used for power transmission in one direction only.

Representation of screw thread: It is very laborious to draw a screw thread in its actual helical form. A screw so drawn naturally looks nice, but serves no other special purpose. Hence screw threads are generally always represented by symbols which can be easily and quickly

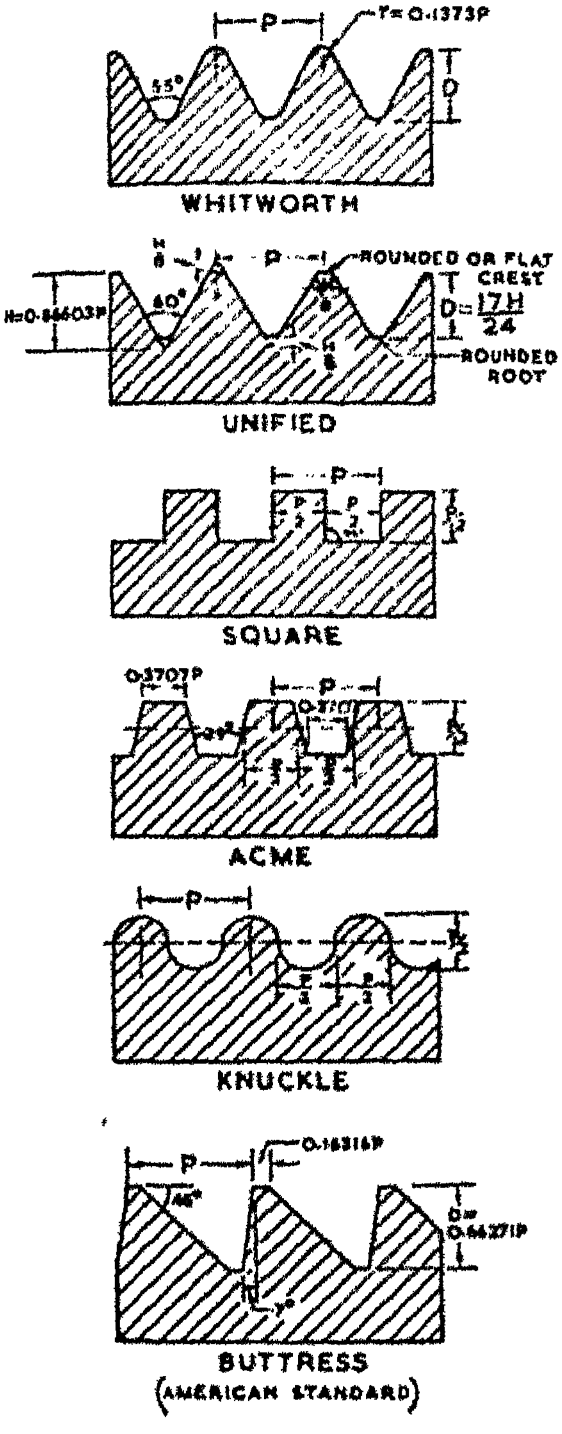


Fig. 8.2 Various screw thread profiles

drawn. Notes are given on the drawing stating the particulars like thread form, pitch, diameter, left hand or right hand.

Conventional symbols as recommended by the Indian Standards Institution (IS: 696—1960) for external and internal screw threads are shown in Fig. 8.3.

A detailed representation of a V-thread and a square thread are shown in Fig. 8.4 and Fig. 8.5 respectively. The steps are:

(i) Draw centre line, length, major diameter and minor diameter of thread.

(ii) Draw a line perpendicular to the axis at one end.

(iii) For a right-hand thread mark off a distance P/2 on the end of the upper line and for a left-hand thread do the same on the lower line. For a R.H. thread the threads slope downward towards left and for an L.H. one just the reverse when the threads are external. For internal threads shown in section, it is just the opposite.

(iv) Draw the thread form between the major and minor diameter lines, as shown, at pitch distances.

(v) Join crest to crest and root to root. For square thread join the corresponding points of the square but keep those portions only which are visible.

8.3 Bolts, Rivets, and Other Fasteners

Introduction: Various types of fasteners are used to connect different elements of machines and structures. Some of them are temporary like bolts and nuts, screws, studs, pins, clips, etc.; others are permanent like rivets.

Bolts, nuts and studs: A bolt is a long round rod with screw threads at one end and a hexagonal or square head at the other end. The bolt is designated as hexagonal head or square head accordingly, Fig. 8.8, and Fig. 8.9.

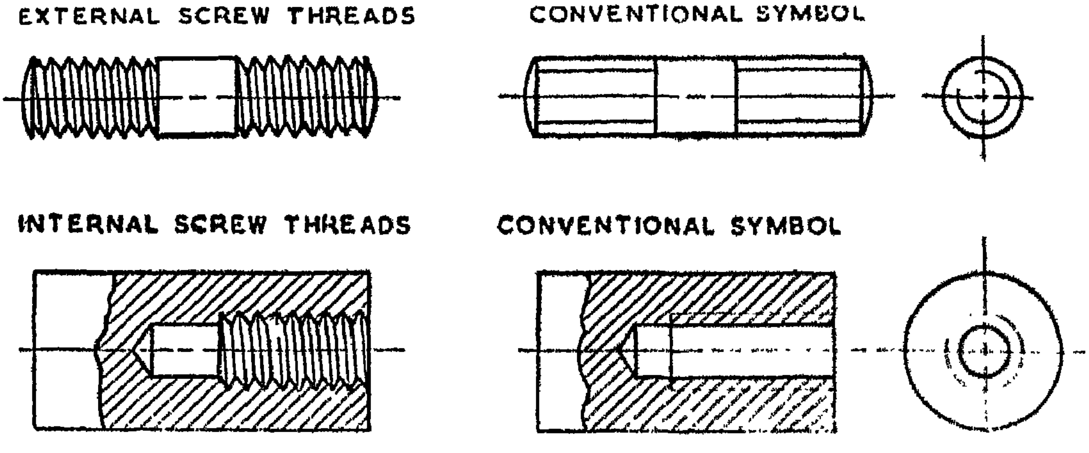


Fig. 8.3 Conventional symbol for representing screw thread

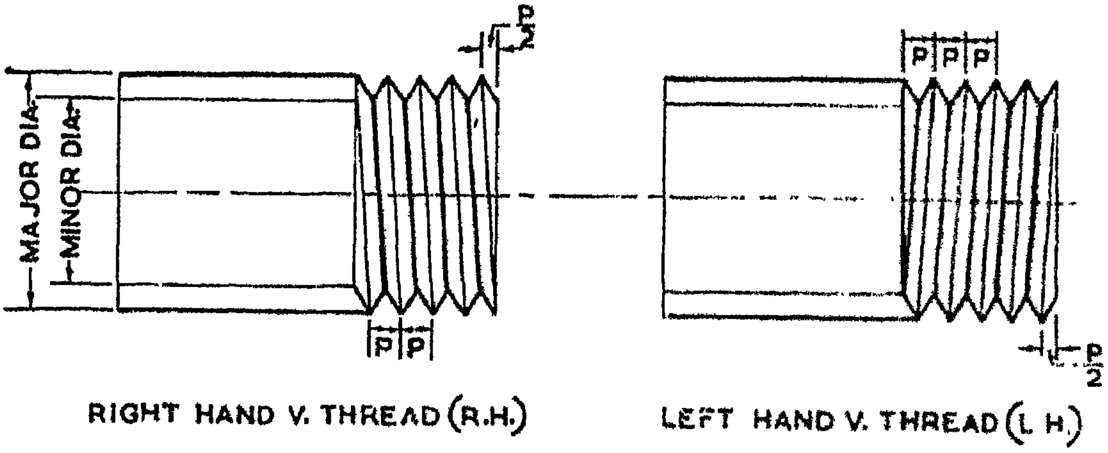


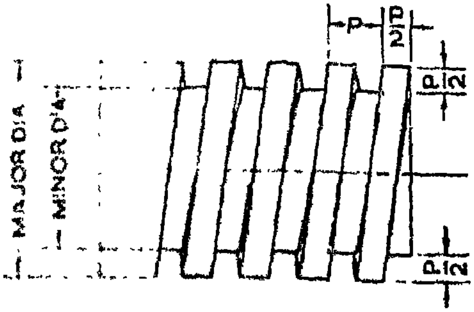
Fig. 8.4 Drawing of V-thread

A nut is a similar hexagonal or square body with a threaded hole running through it. A bolt is generally used with a nut through an unthreaded drilled hole (Fig. 8.6.).

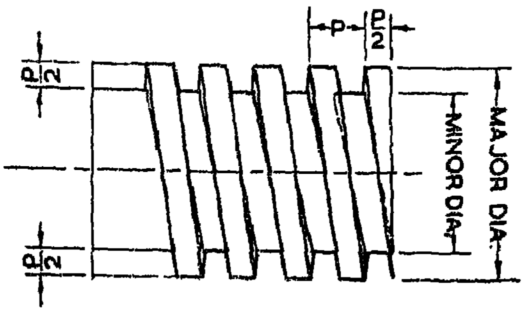
A bolt and a capscrew or tap-bolt are almost the same in appearance, the difference being in their applications. A capscrew is used in a threaded hole directly without a nut. A stud (Figs. 8.3 and 8.6) is a pin whose both ends are threaded. One end is screwed in a threaded hole in a solid body. The other end is used with a nut for fastening another body to it. Sometimes washers are used for proper seating of the nut.

Representation of tapped hole: (Fig. 8.7). The steps in drawing are similar to the steps of the workshop method. At first the drilled hole is drawn. Then the length of the inside thread is shown. In Fig. 8.7 (c) the stud is shown in position. The gap between the thick line of the hole and the thin line showing the thread is approximately equal to the depth of the thread.

Drawing of bolts and nuts: Bolts, nuts, screws, studs are not shown in longi-



L.H. SQUARE THREAD



R.H. SQUARE THREAD

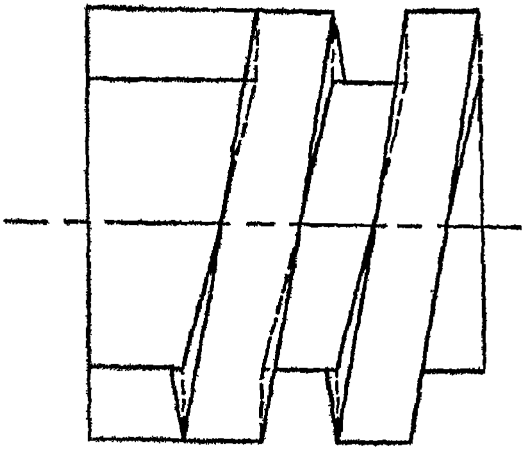


Fig. 8.5 Drawing of square thread

tudinal section. Although the adjacent parts are shown with section lines, these fasteners are shown in full (without section).

These fasteners are manufactured in large quantities and their dimensions are standardized. So in most cases the detailed drawing of bolts, nuts, etc., are not necessary. Simply designation of their sizes and particulars are sufficient. But in assembled views of a machine, it may be necessary to show bolts and nuts in position. In such cases, the actual sizes are shown only approximately and they are not dimensioned. The actual sizes are to be obtained from Indian Standard Specifications.

The usual approximate method of representing a bolt head or a nut is as follows :

(i) If D be the diameter of the shank or body of the bolt, draw a circle with 3/4 D as radius.

(ii) Draw with the help of 60° set-square and the T-square a regular hexagon outside the circle such that the sides of the hexagon touch the circle. This represents now the top view of the hexagonal bolt head. For square-head bolts the procedure is similar. Only instead of a hexagon a square has to be drawn tangentially outside the circle with the help of a 45° set-square.

(iii) Draw a rectangle to represent the bolt head by projecting from this view and making the thickness of the head as 2/3D. Draw parallel lines symmetrically about the centre line with distances D/2 on either side to represent the body or shank of the bolt and make it equal to the given bolt length. This dimension as well as the threaded length can be found from the Indian Standard Specifications (ISS). Represent the threaded length with the help of conventional symbol and show a 45° chamfer at the free end.

(iv) The projection from the top view may be drawn across flats or across corners. To avoid confusion, it is better to draw generally a hexagonal head across corners and a square head across flats.

To draw the hexagonal head across corners use the method shown in Fig. 8.8.

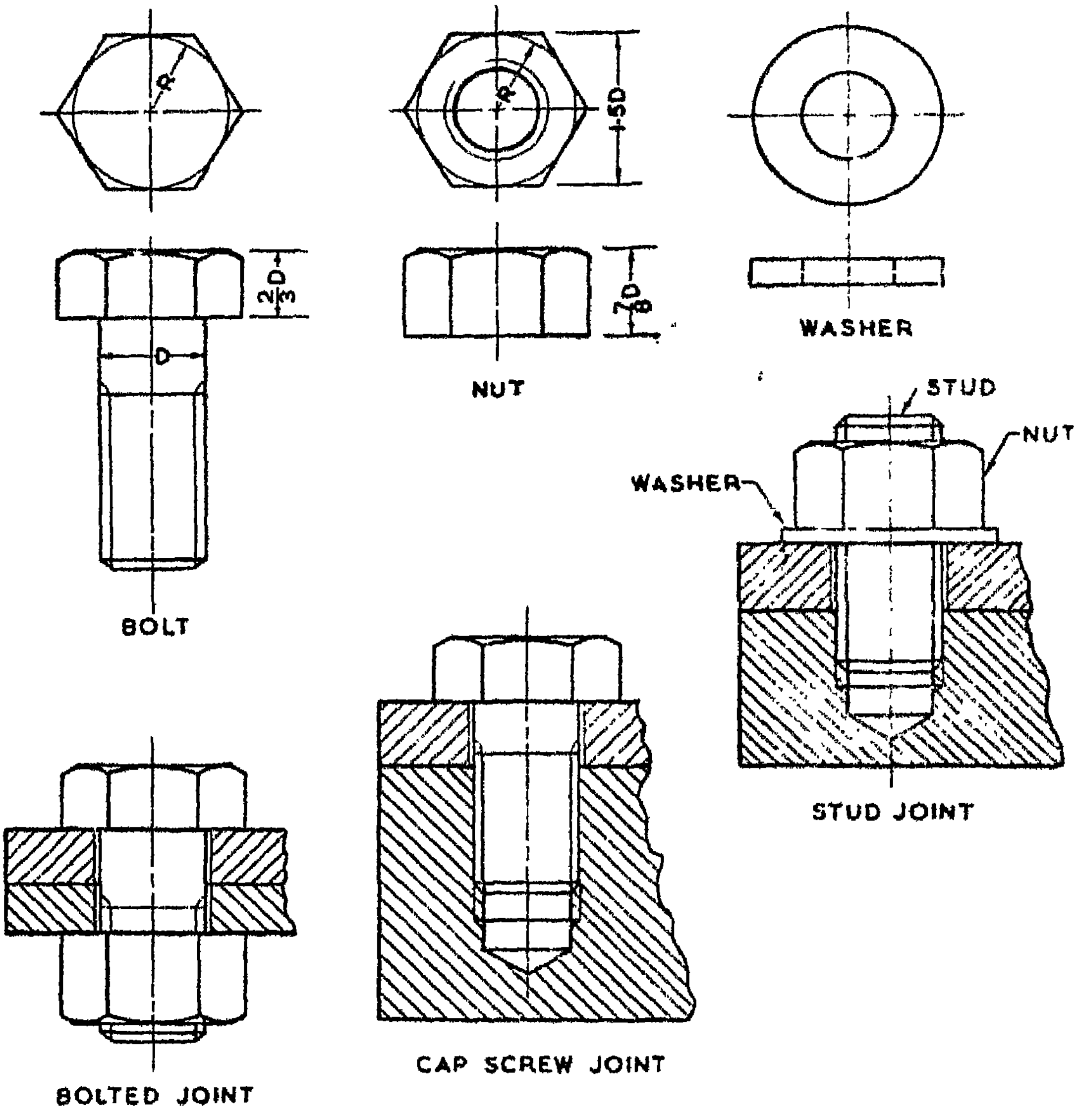
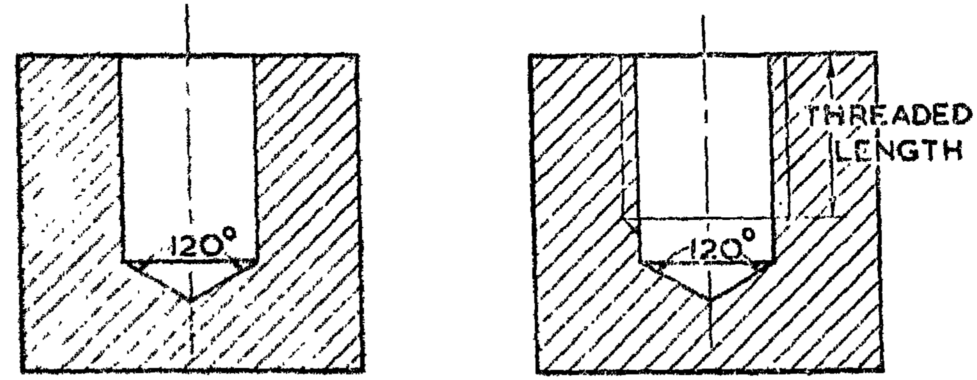
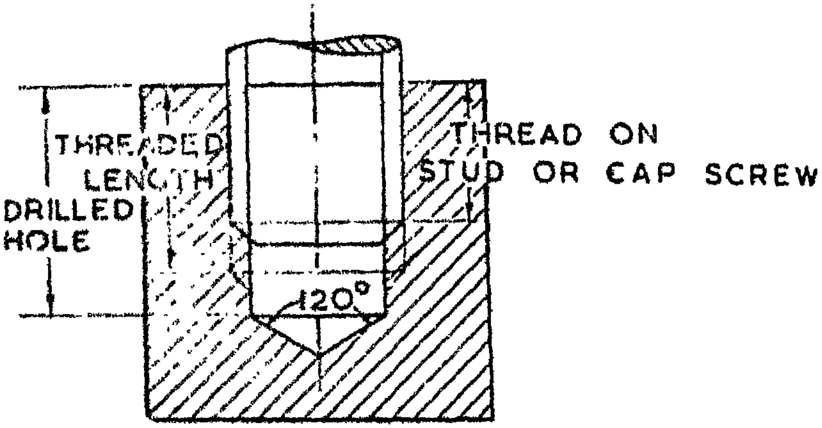


Fig. 8.6 Representation of bolts, nuts, washers, studs, cap screw and their joints

Starting with the rectangle described in (iii) it is drawn in the following manner. Through the two outside top corners draw construction lines, each of which makes an angle of 30° with the axis. With this point of intersection as centre and a radius 'R' equal to the distance up to the top, draw an arc. This represents the middle part of the head. From the two inside corners draw similar lines cutting the previous construction lines at 60°. Taking these points as centres and radius equal to the distance up to the top, draw two arcs. Finally draw tangential to these arcs 30° chamfer lines at the outer corners of the head. Now erase construction lines and make the visible lines darker.



(a) DRILLED HOLE (b) TAPPED HOLE



(c)

Fig. 8.7 Representation of blind tapped hole

The method of drawing a square-head across corners is similar and is shown in Fig. 8.9.

To draw this, first project from the corners of the square. Draw four construction lines, two from the corners and two from the middle, making each of them inclined to axis at 30°. With the two points of intersection as two centres and with a radius up to the top line, draw two arcs. Then draw the 30° tangential chamfer lines at outside corners.

Drawing a square-head across flats is still simpler. By making a proper projection, the rectangle is drawn first. Only one arc is visible, which is tangential to the top line. The centre of this arc is on the axis and the radius is 2D. No tangential chamfer lines are to be drawn, Fig. 8.9(a).

Similarly, a hexagon head across flats is drawn. Draw the head rectangle first by appropriate projection. This rectangle is divided into two equal parts by the centre line. Draw the middle line of each of these two smaller rectangles, Fig. 8.8(b).

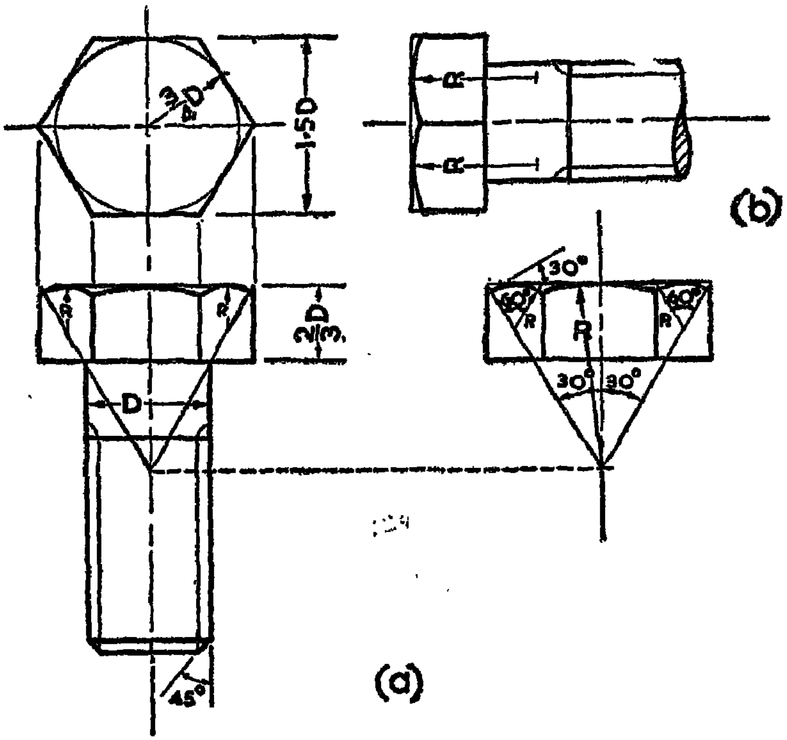


Fig. 8.8 Drawing of hexagonal bolts head

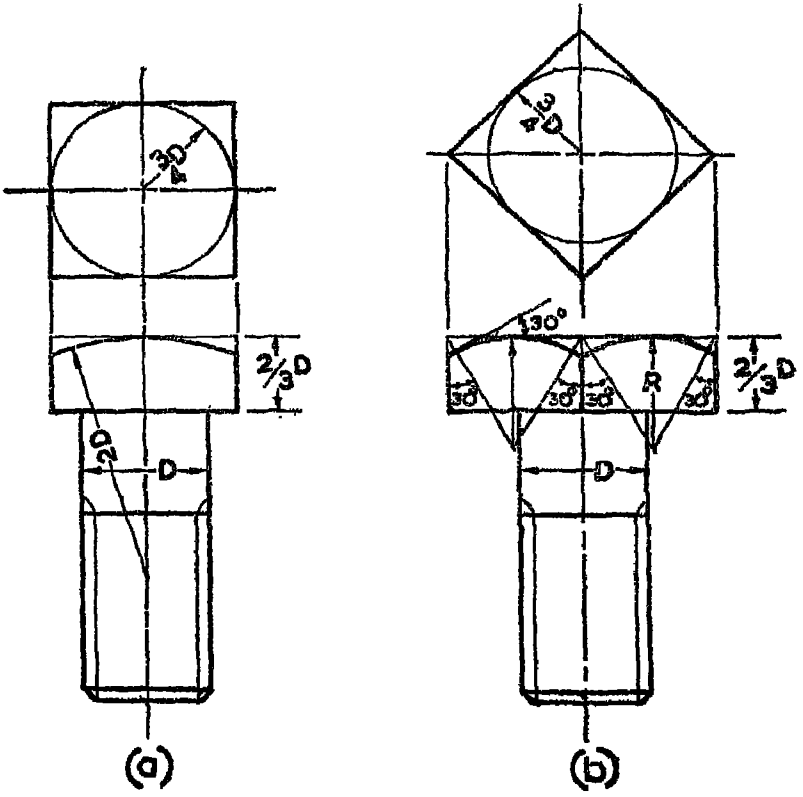


Fig. 8.9 Drawing of square bolts head

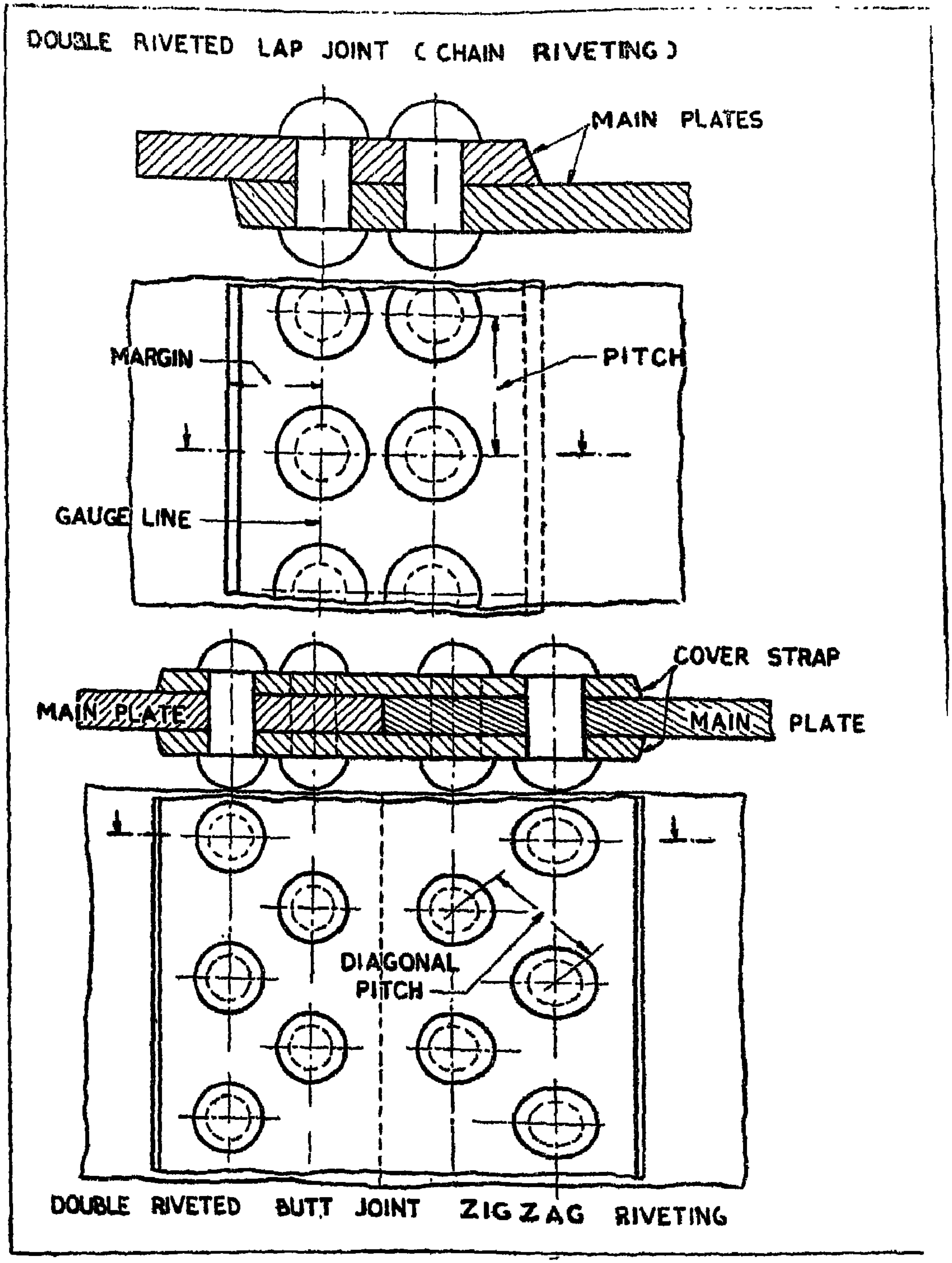

DOUBLE RIVETED LAP JOINT (CHAIN RIVETING)
MAIN PLATES
MARGIN
PITCH
GAUGE LINE
COVER STRAP
MAIN PLATE
MAIN PLATE
DIAGONAL PITCH
DOUBLE RIVETED BUTT JOINT ZIGZAG RIVETING

Fig. 8.10 Riveted joint

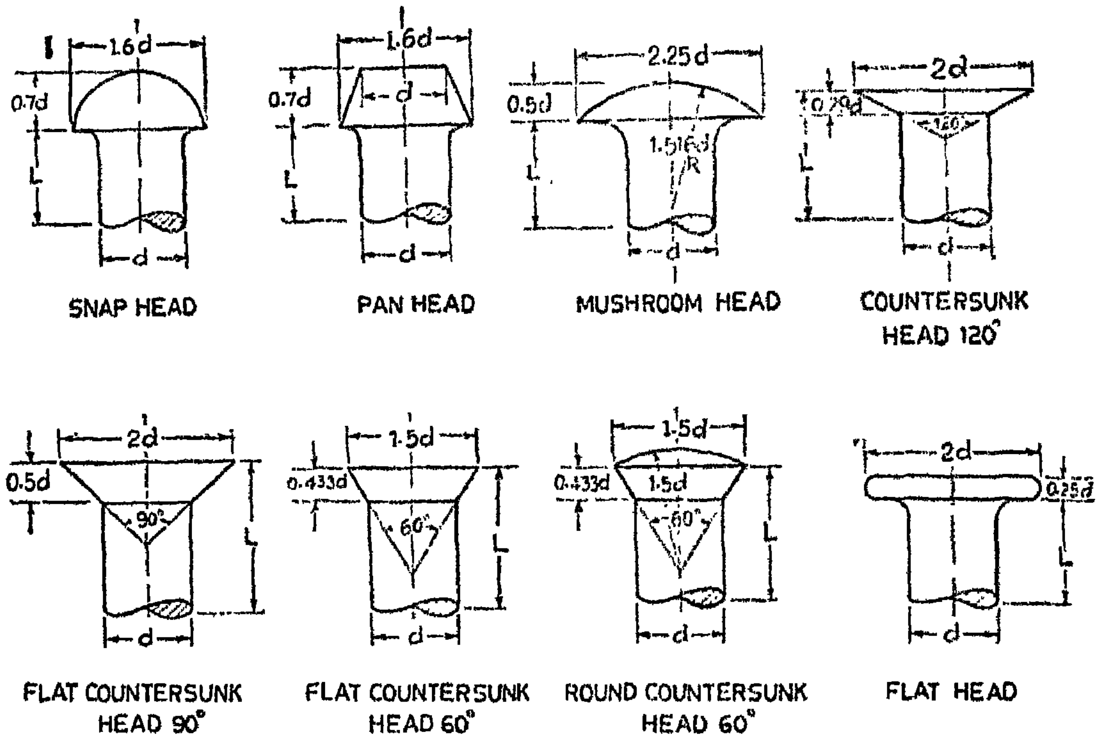


Fig. 8.11 Various types of rivet heads

Taking a radius equal to D and locating the centres on these middle lines by trial, draw arcs touching the top line. No other chamfer line is to be drawn.

Nuts are drawn similarly. The thickness of nuts may be taken as 7/8D for drawing purpose, although the actual thickness is something different. For actual thickness ISS has to be referred to.

Rivets: A rivet is a straight rod with a formed head at one end. It is used to fasten two plates permanently. Holes are made by drilling or punching on these plates at proper distances and then the plates are so placed that the holes of one plate come directly over the holes of the other plate. Rivets are put into the aligned holes. The head of a rivet is held tightly on the plate and the free end is held in a die and hammered or pressed to give it the shape of another head. Larger rivets are pre-heated, smaller rivets may be driven cold. Now, with two heads on either side the rivet forms a permanent fastening, that is, it cannot be removed or opened very easily, Fig. 8.10.

Types of rivets: Some of the common types of rivets are illustrated in Fig. 8.11, with dimensions according to ISS. The snap head is the most common type. Countersunk heads are used to get a flush surface.

Types of riveted joints: (Fig. 8.10) The two common types of riveted joints are: (1) Lap joint and (2) Butt joint. In a lap joint, one plate is put above the other (known as lapping) and then riveted. This type of joint is designated according to the number of rows of rivets. Thus, a single riveted lap joint means one row of rivets, a triple riveted lap joint means three rows and so on.

In a butt joint, the two plates are placed butting against each other, that is, side by side along a common edge. Another plate, known as a cover plate or cover strap is placed over the common edge, and then the two main plates are riveted individually to this common cover plate. Sometimes instead of one strap, two cover straps are used on either side of the joint. A single strap is usually of the same thickness as that of the main plates. For double straps the thickness of cover straps is usually half of the main plate. The joint is designated according to the number of rows of rivets on each main plate.

Some technical terms defined: (Fig. 8.10)

Pitch is the distance from centre to centre of two consecutive rivets in a row, parallel to the edge or seam.

Margin is the least distance from the centre of the rivet nearest to the edge, to the edge of the plate. It is almost 1.75d where 'd' is the rivet hole diameter.

Gauge line is the line joining the centres of rivets in a row parallel to the seam.

Zigzag and chain riveting: When the line joining the centres of two rivets in consecutive rows is perpendicular to the gauge line, it is called chain riveting. In any other case, it is called zigzag riveting.

Diagonal pitch is the distance between the centres of two rivets in consecutive rows in a *zigzag* riveting.

Rivet symbols: In a large drawing where thousands of rivets are used, it is not necessary to draw all the rivets. The gauge lines are drawn and the locations of the rivets are shown on this line by a thick '+' symbol. Sometimes riveting is done in the workshop. These are shown in the drawing with a note—"SHOP RIVETS".

For very large structural parts, however, a considerable number of riveting has to be done on worksite, i.e., the place of erection. In drawing, it is shown with a note—"SITE RIVETS". The symbols of riveting according to IS: 696—1960 are shown in Fig. 8.12.

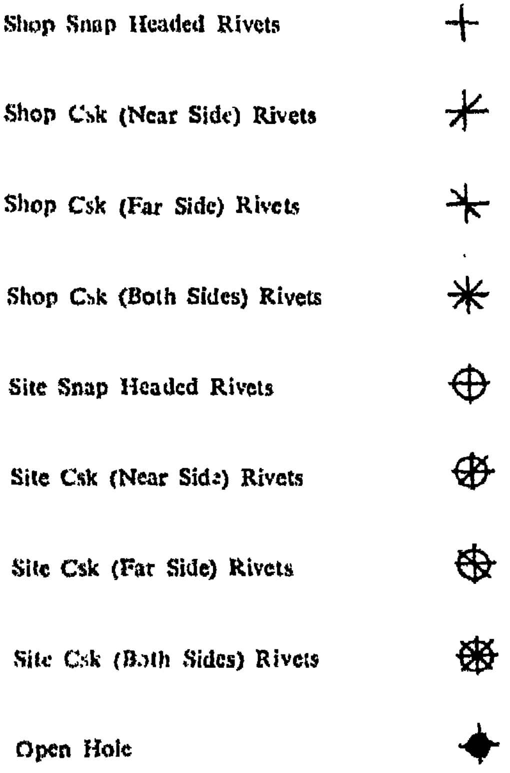

Shop Snap Headed Rivets
Shop Csk (Near Side) Rivets
Shop Csk (Far Side) Rivets
Shop Csk (Both Sides) Rivets
Site Snap Headed Rivets
Site Csk (Near Side) Rivets
Site Csk (Far Side) Rivets
Site Csk (Both Sides) Rivets
Open Hole

Fig. 8.12 Rivet symbols

For countersunk rivets the abbreviation "Csk" is used. By "Near Side" the side shown in the drawing is meant. "Far Side" means the other side of the plate.

Other fasteners: Besides various types of bolts, nuts, screws and rivets other types of fasteners are also used frequently. Various types of pins, cotters and keys are examples of these.

8.4 Keys and Keyways

When a wheel or pulley or some other

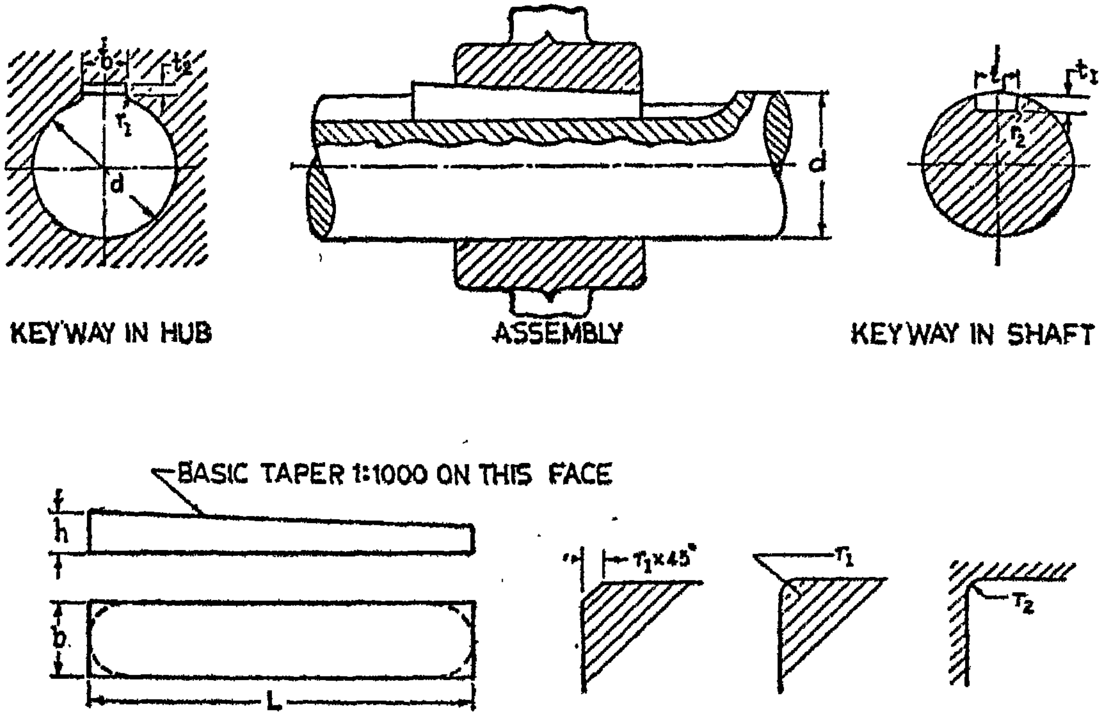


Fig. 8.13 Taper key and keyway

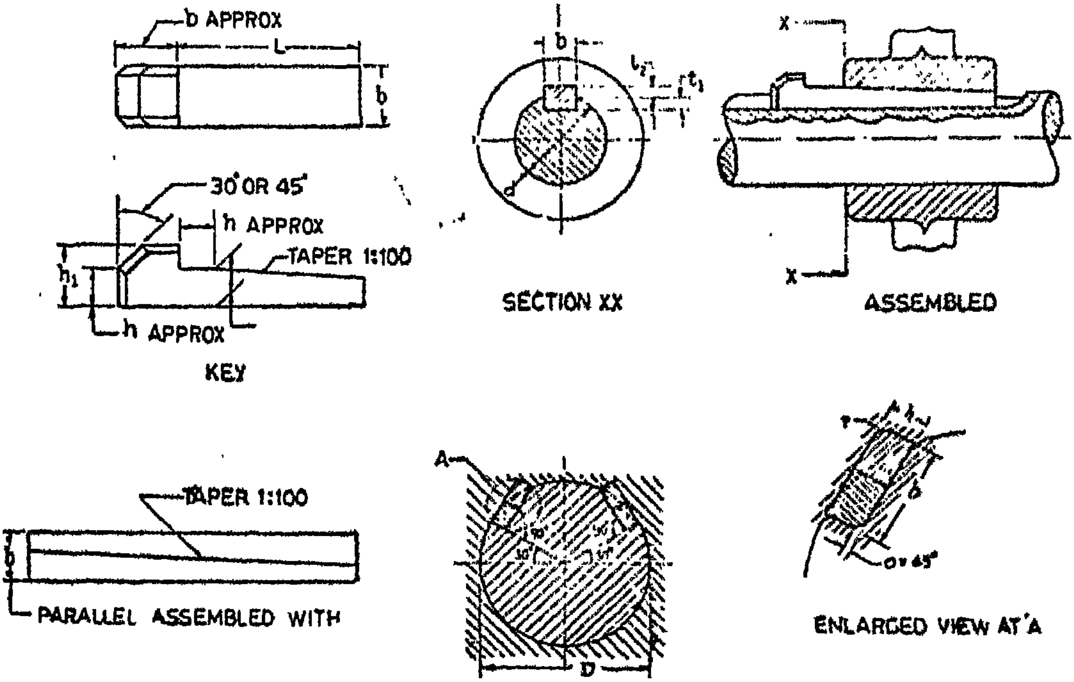


Fig. 8.14 Gib head key and tangential key

similar things (called mountings) have to be fixed on a shaft such that they rotate with the shaft, a key is generally used as the fastener.

A key is usually a metallic piece suitably inserted between a mounting and a shaft to prevent relative rotary movement between them. It is a temporary fastener as it can be removed easily.

For the positioning of the key, usually grooves are cut on the shaft as well as on the inside surface of the hub of the mounting. The groove is called the keyway.

Types of Keys and Keyways: Some of the typical keys are shown in Fig. 8.13 and Fig. 8.14. The actual dimensions are given in the specifications of ISI (IS: 2291—1963, IS: 2292—1963, IS: 2293—1963, IS: 2294—1963) and are to be taken from it for drawing purpose, and should be designated as follows:

Taper Key 10 × 8 × 80 IS: 2292 meaning thereby a taper key of width 10 mm, height 8 mm, and length 80 mm.

8.5 Cams and Gears

Cams: A cam is a body, having an irregular contour, which can impart intermittent motion, as it rotates, to a second body called the follower. The follower is guided and remains in contact with the contour of the cam. Many types of cams and followers are possible. The disc cams shown in Fig. 8.15 and Fig. 8.16(b) are common ones. The type of follower shown is called the knife edge follower. Our discussion here will be restricted to these types of cams and followers only.

Displacement diagram: Motion of the follower is usually of reciprocating or of the to-and-fro type. But this is not regular either. While the cam is rotating uniformly about its axis, the follower may move away from the cam centre for some time, it may remain there for some time; and then come back to its original position.

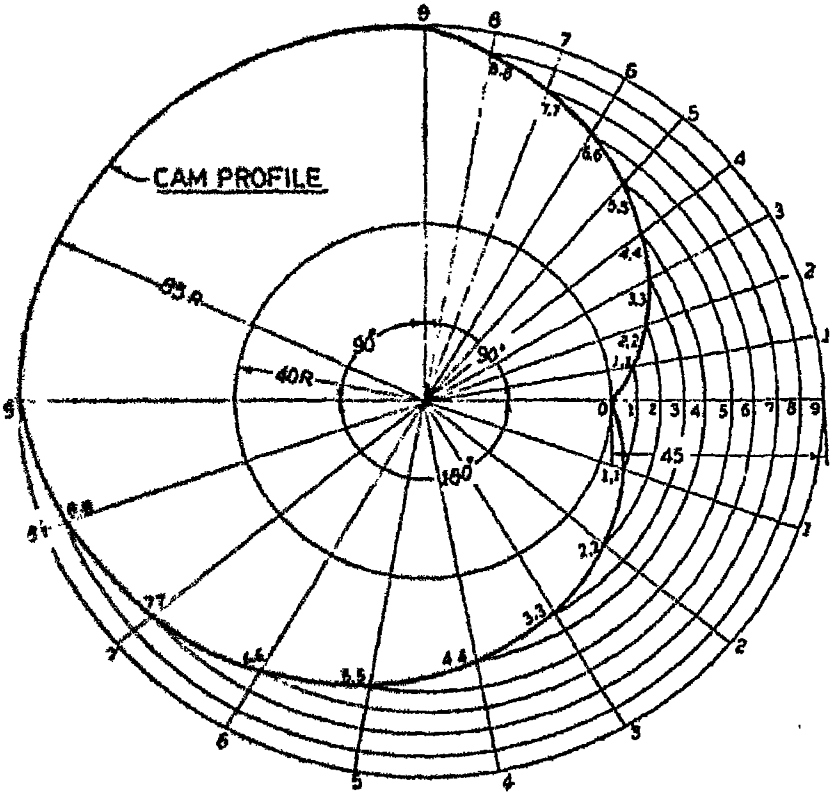


Fig. 8.15 Cam profile with uniform lift and fall

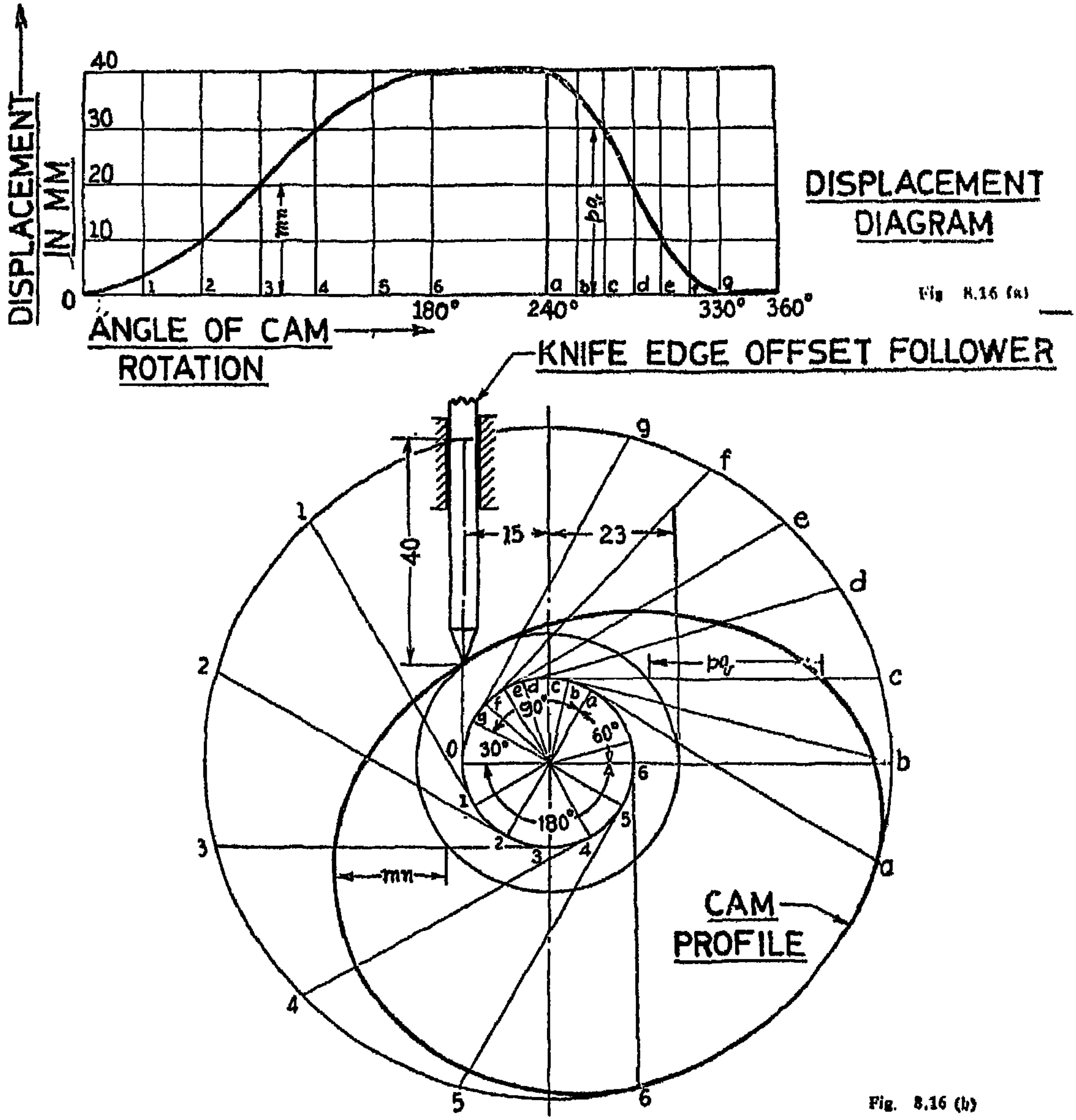


Fig 8.16 (a)

Fig. 8.16 (b)

Fig. 8.16 Drawing of cam profile for given displacement diagram

It may go on repeating this sequence of movement over and over again. The movement of the follower is called displacement. If on a graph, the displacement of the follower in mm. is plotted as ordinate and the corresponding cam rotation in degrees as abscissa, the diagram is called the displacement diagram Fig. 8.16 (a).

The problem of cam drawing is to find out the cam contour or profile when the displacement diagram or the condition of displacement of the follower are given.

It will be illustrated by a couple of problems.

Problem 1: Draw the profile of a disc cam such that its knife-edge follower remains at least 40 mm. away from the cam centre. The follower is guided in such a manner that its line of motion passes through the cam centre. For 180° of cam rotation the follower should move away from the cam centre (lift) by 45 mm. with uniform speed. It should remain there (dwell period) for 90° of cam rotation and then come back to its original position (fall) with uniform speed during a further 90° of cam rotation. The cam rotates with uniform angular speed.

Procedure : (Fig. 8.15)

(i) Draw a circle with 40 mm. radius (given minimum distance) and extend the radius by further 45 mm. (given maximum lift of cam). Draw another circle with 40 + 45 = 85 mm. radius.

(ii) Divide the 45 mm. distance into some convenient number of equal divisions (9 divisions are shown here) and number them as 1, 2, 3, etc.

(iii) At the centre of the circle lay out 180° (the lift period), 90° (the dwell period), and 90° (fall period). Divide the lift and fall periods into 9 equal angular divisions each and draw radial lines through these divisions and number them 1,2... etc. for the lift before dwell and 9, 8, 7.... etc. for the fall after dwell. At dwell the radius of profile remains constant (85 mm.).

(iv) With the centre of cam as centre, draw arcs as shown through 1, 2,......etc., and note the points of intersection with radial lines as 1,1; 2,2;... etc., and draw a smooth curve through these points. This curve is the required cam profile.

Sometimes the displacement diagram is given. This should be drawn to scale so that the ordinate (displacement) has the same scale as that of the cam to be drawn. The abscissa (angles of cam rotation) may be plotted to any convenient scale.

Problem 2 (Fig. 8.16 a, b): Draw the profile of a disc cam with the given displacement diagram for a knife-edge follower whose line of action is 15 mm. offset from the cam centre. The sequence of motion is as follows:

Lift 40 mm. for 180° of cam rotation,
Dwell there for 60° of cam rotation,
Fall 40 mm. for 90° of cam rotation,
Dwell there for 30° of cam rotation.
Total: 360°

The minimum radius of the cam should be 23 mm.

Procedure: (i) Draw a circle of 23 mm. (minimum radius) radius and concentric to it another circle of 15 mm. radius (offset). (ii) At the centre of the circles lay out 180° (lift), 60° (dwell), 90° (fall), and 30° (dwell) respectively. Draw radical lines as before and divide the lift and fall periods into some equal number of divisions. Here the divisions have been named 1, 2, 3,...etc. for the lift period and a, b, c,...etc. for the fall period. The same numbers and letters are given on the displacement diagram also.

(iii) At the points of intersection of the radial division lines and the offset circle draw tangential lines on the offset circle. These tangents should be drawn in the same direction. These lines are 1-1, 2-2, 3-3,...etc., and a-a, b-b, c-c...etc.

(iv) Measure off the displacements from the graph with a divider at the points 1,2,3... a,b,c,...etc. and plot them on the tangential lines just drawn. The plot should be measured from the minimum radius circle and outside of it. As an example, the distances mn and pq are shown on tangential lines 3-3 and c-c respectively, and these are also shown in the displacement diagram. At dwell period, there is no change of measurement.

(v) Join the points as laid out at the tips of the tangential lines by a smooth curve and the required cam profile is there.

Gears: Gears are the same thing as toothed wheels. They are used for transmission of rotary power from one shaft to another, usually with some change of speed. A type of straight gear is used for getting a linear motion from a rotary motion or vice versa. Its name is rack.

Types of gears: Different types of gears are used for different types of shaft arrangement. The common types are:

Spur gears, which are used for parallel shafts;

Bevel gears, which are used for intersecting shafts; and

Skew gears, which are used for non-parallel, non-intersecting shafts. Screw gears, worm gears, hypoid bevel gears are examples of this type.

When the teeth of a spur gear are parallel to the axis, it is called a straight tooth spur gear. Sometimes the teeth of spur gears are inclined to the axis in the form of a helix. Such gears are called helical or spiral teeth spur gears. Here, only the drawing methods of straight tooth spur gears have been discussed.

Terminology: Students should be thoroughly familiar with certain special terms in connection with drawing a gear, as follows: (See Fig. 8.17 a, Fig. 8.18).

Pinion is the smaller wheel of a gear pair. The larger one is called a gear or simply wheel.

Pitch Circle: Gears are designated according to the size of this circle. This is the size of an equivalent friction wheel to transmit the power with the same change of speed. This circle must be shown in the drawing, approximately midway between the tip and root of the teeth. This circle divides the tooth and gap equally for gears of standard proportions.

Circular Pitch: is the arc distance on the pitch circle between similar points on consecutive teeth.

Module: is the ratio of the pitch circle diameter in mm to the number of teeth on the gear.

Diametral Pitch: is the reciprocal of module. It is usually denoted by the ratio of the number of teeth to the pitch circle diameter in inches.

Addendum: is the height of the teeth above the pitch circle.

Dedendum: is the depth of the tooth below or inside the pitch circle.

Clearance: is the difference between dedendum and addendum.

Calculations: If N denotes the number of teeth, and D the pitch circle diameter, we have,

Module $= D/N$, and Diametral Pitch $= N/D$; and Circular Pitch $= \pi D/N$, Module $\times \pi =$ Circular Pitch; and (Circular Pitch) × (Diametral Pitch) $= \pi$. If $N\pi$ and $N\pi$ are the numbers of teeth on pinion and gear respectively and m is the module (Module, Diametral Pitch, and Circular Pitch should be the same for both pinion and gear), the centre distance between pinion and gear axes $= m/2\,(N_1 + N_2)$. The standard dimensions of gear teeth are:

Addendum = Module, Dedendum = $1.25 \times$ Module.

Tooth Profile: The priofile of a gear tooth is a curve called involute. This curve is generated by the free end of a rope, when the latter is unwound from the surface of a cylindrical barrel. The construction of this curve is shown in Fig. 8.17 (b) and is as follows:

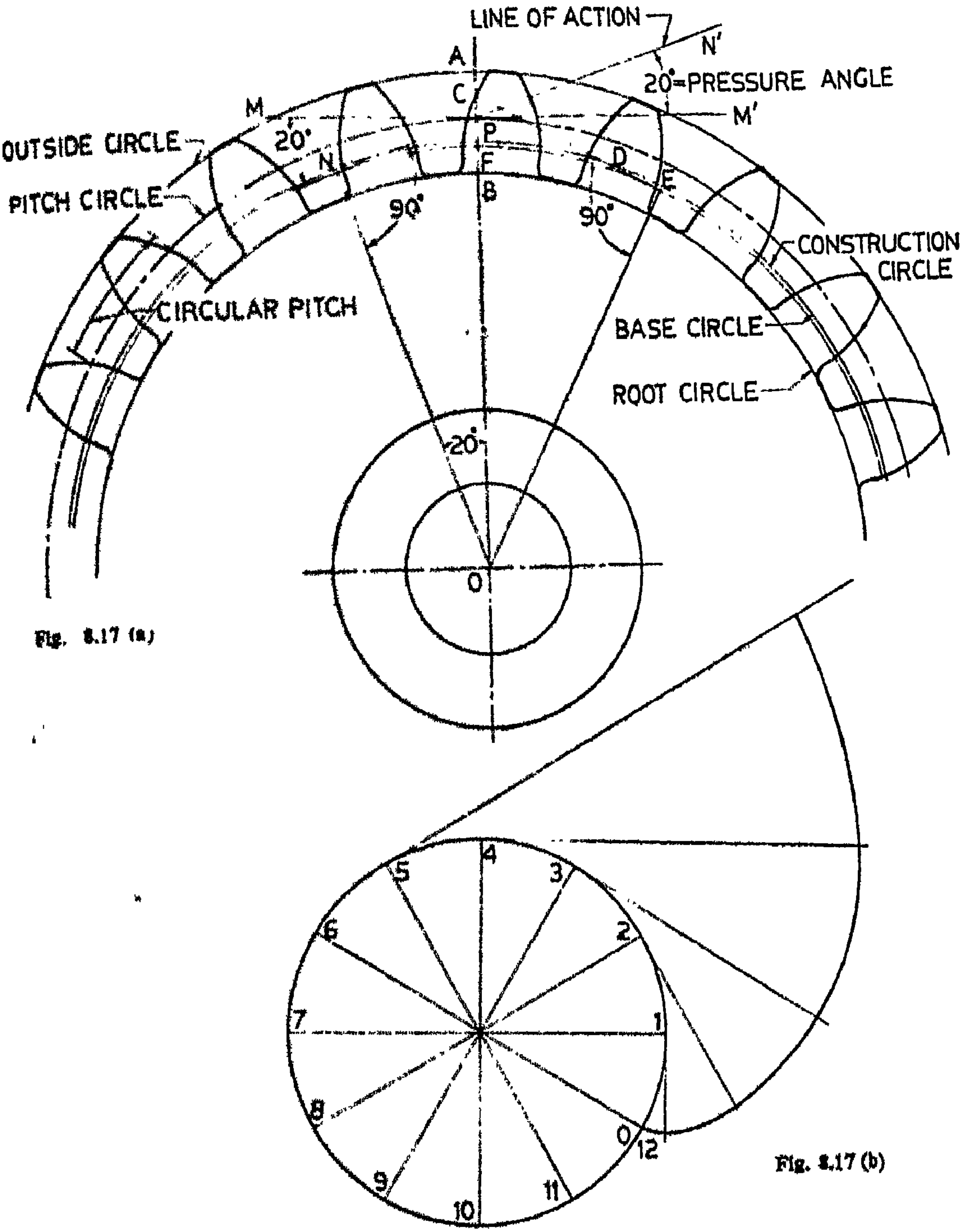


Fig. 8.17 (a)

Fig. 8.17 (b)

Fig. 8.17 Drawing of involute curve and gear tooth profile

(i) Divide the circumference of a circle into a number of parts. Here 12 divisions have been made with a 30° set-square. Draw tangents from each of these points on the circle and in the same direction.

(ii) Make the length of the tangent at the point next to the starting point equal to the arc length between these two points. Similarly, make the length of the tangent at any other point equal to the arc length between that point and the starting point.

(iii) Join the free ends of the tangents by a smooth curve and this is the involute.

The circle from which the involute is generated is known as the base circle.

Drawing of Gear Teeth: For accurate drawing, the profiles on either side of a gear tooth should be drawn as a part of an involute curve. It is, however, a very laborious process and hence simplified approximate methods are followed for drawing the gear tooth profile.

Fig. 8.17 (a) shows the approximate method of construction of gear tooth by Prof. Unwin's process.

O is the centre of the gear. With centre at O three concentric circles are drawn. OP is the pitch circle radius. OA is the outside radius and OB is the root radius.

$$\frac{OP = (\text{module}) \times (\text{number of teeth})}{2};$$

where module and number of teeth are given.

$OA = OP + PA = OP + \text{Module} = OP +$ (Addendum)

$OB = OP - PB = OP - 1.25$ (Module) $=$ OP—(Dedendum)

At P, MPM′ is drawn perpendicular to OP. NPN′ is drawn at P making an angle of 20° with MPM′. This angle is known as pressure angle. The commonly used values of this angle are 20° and $14\frac{1}{2}°$. The pressure angle here is $\angle NPM = \angle N'PM'$. According to ISS the pressure angle should be 20°.

The line NPN′ is known as the line of action. Contact points of involute teeth always lie on this line. Draw a circle with O as centre and tangential to the line NPN′. This is the base circle of the involute profiles. Let this circle cut the line OA at F.

Now AF is divided at the point C such that $AC = \frac{1}{3}AF$. From C a tangent CE is drawn on the base circle. CE is divided at D, such that $CD = \frac{1}{4}CE$. With D as centre and CD as radius an arc is drawn between the outer circle and the root circle. This is the approximate involute profile of the tooth. The continuation of this profile near the root circle is rounded with a suitable fillet radius.

Now the pitch circle is divided into arcs of length equal to half the circular pitch. Through D a circle is drawn with centre at O. This circle is only a construction circle. Now finding the centres on this circle by trial and with radius equal to CD, draw arcs through the points of division of the pitch circle.

If the root circle is smaller than the base circle, the arc profile of the tooth should stop at the base circle and it should now continue towards the centre as a radial line up to the root circle. A number of teeth have been drawn in this way and shown in Fig. 8.17 (a).

A still simpler but approximate method is to use the distance NP as radius for drawing tooth profile arcs, using the base circle as the construction circle. Fig. 8.18 is drawn in this way and it shows a gear pair in mesh.

Symbols for representing gears are shown in Fig. 8.19 as recommended by ISI.

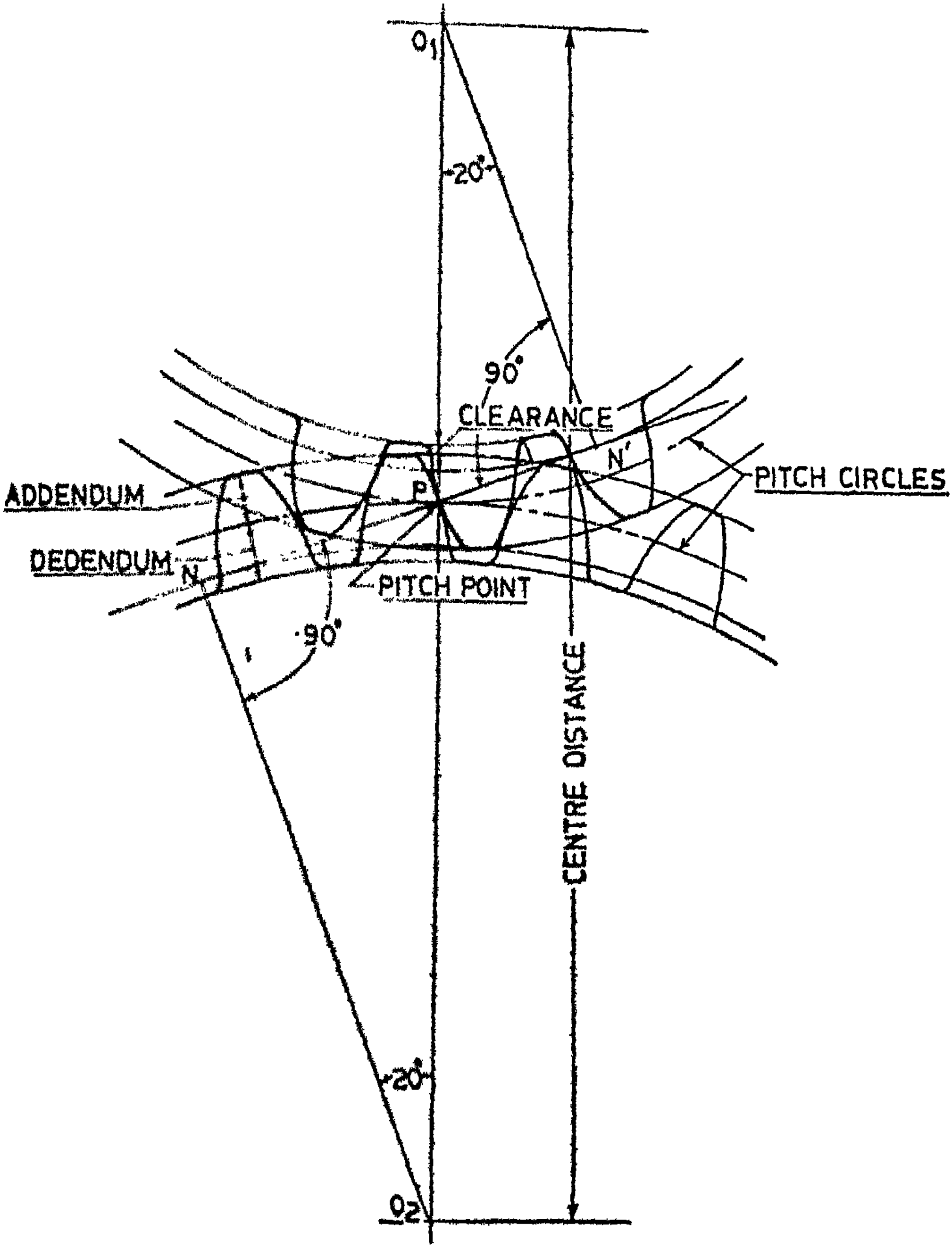


Fig. 8.18 Drawing of gear teeth in mesh

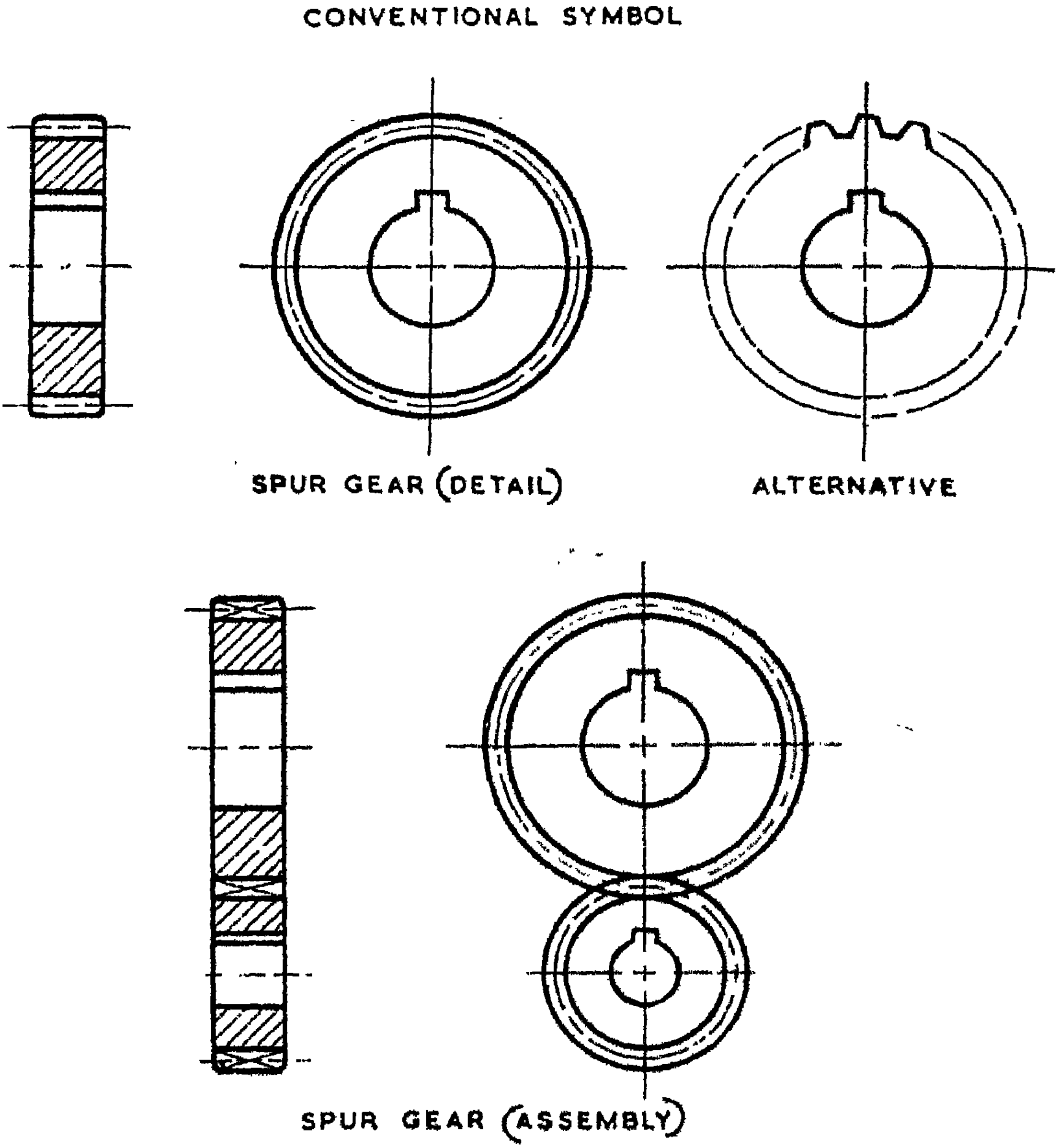
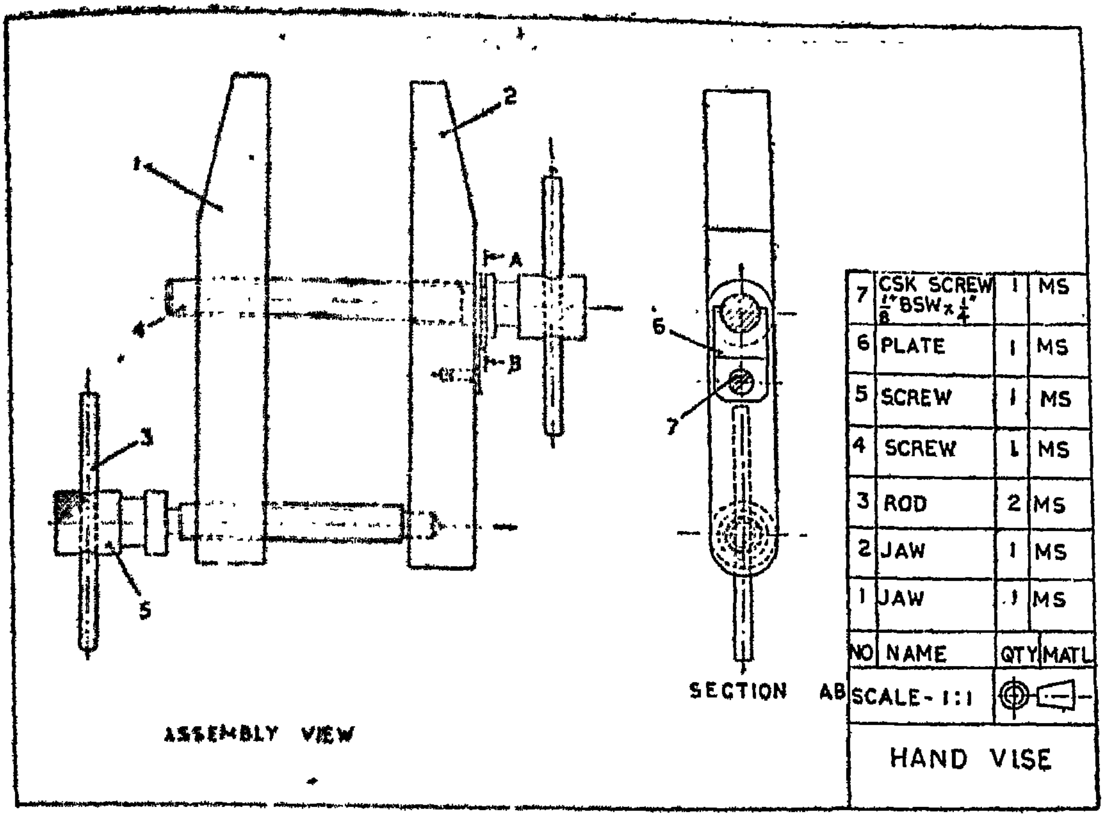


Fig. 8.19 Conventional symbols for gears

8.6 Simple Machine Parts and Assembly Drawings: (Fig. 8.20 a, b)

A machine usually consists of several parts. A part is called an element or detail. In general, these elements are connected to each other or separately to a main central body by means of fasteners. The shapes and sizes of these bodies are decided by the designer. In determining the shape and size of an element, the designer keeps in mind the function of that element as well as the method of manufacturing of that body.



NO	NAME	QTY	MATL
7	CSK SCREW $\frac{1}{8}$"BSW x $\frac{1}{4}$"	1	MS
6	PLATE	1	MS
5	SCREW	1	MS
4	SCREW	1	MS
3	ROD	2	MS
2	JAW	1	MS
1	JAW	1	MS

SCALE - 1:1

HAND VISE

Fig. 8.20 (a)

Fig. 8.20 Assembly and detail drawings of a clamp

The basic ideas of the designer are usually expressed through freehand sketches. But, later, detailed scale drawings have to be made from these sketches for actual production and fitting. Usually there are two steps involved in this drawing process, namely,

(i) an assembled view of the different parts together, and

(ii) drawings of each individual element separately. The first is called an assembly drawing and the second is known as a detailed or detail drawing.

The assembly drawing shows the different parts in their relative positions. To get a complete idea of length, breadth and height, at least two views of the assembly drawing are necessary. To show inner details, which are normally hidden, a full or part sectioning in one of the views may be necessary. Sectioning partly or wholly is a much better way of showing details than a full view without section and a number of jumbled up dotted lines for the inner details. The assembly drawing is necessary for fitting the different parts together.

The detail drawing, on the other hand, is mainly meant for the workshop. It is also called the working drawing. It should describe all the details of just one component taken individually. As this drawing is used for production purpose, it may carry notes regarding surface finish, heat-treatment, tolerances in dimension, etc. Whereas in the assembly drawing

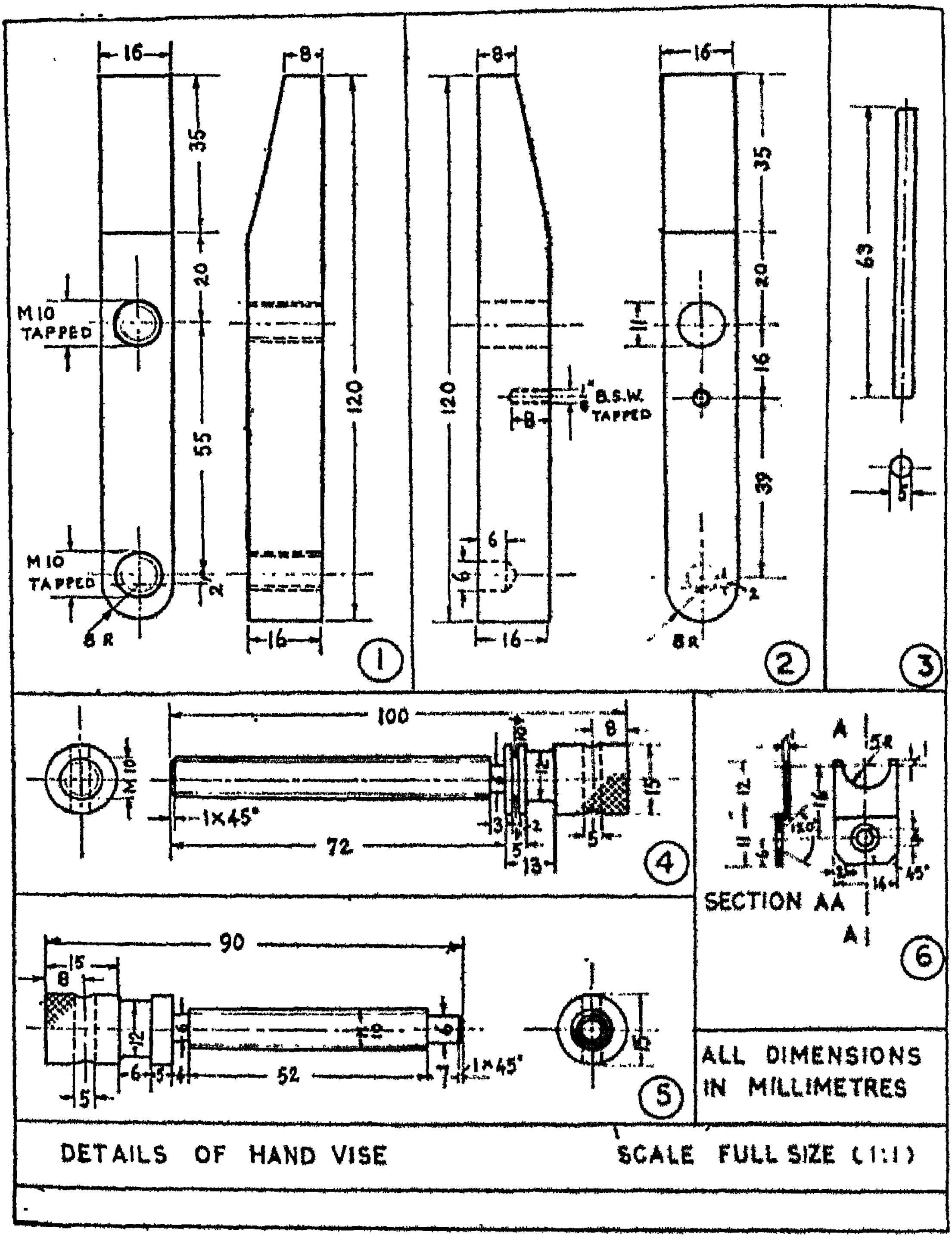

M10 TAPPED
M10 TAPPED
8 R
①
1/8" B.S.W. TAPPED
8 R
②
③
1×45°
M10
④
1×45°
⑤
A
5R
120°
45°
SECTION AA
A
⑥
ALL DIMENSIONS IN MILLIMETRES
DETAILS OF HAND VISE
SCALE FULL SIZE (1:1)

Fig. 8.20 (b)

the overall dimensions should be given mainly, the detail drawing should contain all the dimensions necessary for manufacture.

The Assembly and Details may be drawn on the same sheet if the size of the paper is large (IS recommended size A0 or A1). In the assembly drawing the individual items should be numbered. These numbers should be given to the details in their drawing.

At the right hand bottom corner of the drawing sheet the title block is to be drawn as recommended in IS: 696-1960. The title block should contain at least the following information:

(i) The description or the name of the drawing,
(ii) Scale,
(iii) Name of the firm or institution,
(iv) Drawing number,
(v) Date and signatures of designer and draughtsman,
(vi) A list of components, called the Bill of Materials.

This last item—Bill of Materials—is drawn in a tabular form above the title block. Sometimes this bill of materials is drawn on a separate sheet also.

It should contain the following information about the details:

(i) Item or detail number, usually written from bottom to top to provide space above for further additions,
(ii) Name of the component,
(iii) Material of the component,
(iv) Quantity of each item,
(v) Standard specification number if the item is a standard one like bolts, nuts, etc.
(vi) Space for additional or special remarks.

Detail drawing of standard parts are not necessary. Only the specification number is sufficient.

If the details and assembly are drawn in the same sheet, it is better to use the same scale for all of them, if possible. If different scales have to be used, it should be mentioned near drawings of the parts. The drawing of each detail should be surrounded by a boundary line to avoid confusion with neighbouring drawings. It is, however, preferable to draw the details in separate sheets of smaller sizes like IS A4 (210 × 297 mm.) or IS A5 (148 × 210 mm.), whichever is suitable.

PROBLEMS

1. What is the importance of freehand sketching and how is it done?
2. What is meant by pitch and lead of a screw? What is a right handed screw?
3. Show by drawing a few types of screw thread profiles and mention their uses.
4. What are conventional symbols of representing a screw thread and a blind tapped hole? Draw such a tapped hole with a stud in position.
5. What are temporary and permanent fasteners? Give examples.

6. Draw a hexagonal head and a square-head across corners and across flats for a bolt diameter of 20 mm.

7. Draw a snap head and a 90° flat countersunk head for a rivet of 20 mm. diameter.

8. Define the terms pitch and margin in connection with riveted joints. Draw a double riveted lap joint for two 16 mm. thick plates with rivets of 24 mm., diameter at a pitch of 75 mm. Draw two dimensioned views in full size.

9. Draw in full size a double riveted, zig-zag, butt joint with two cover straps showing two views. Plate thickness 18 mm., cover strap thickness 12 mm. rivets of 20 mm. diameter, pitch 75 mm., margin 1.5 d, distance between gauge lines 2d.

10. For what purpose is a key used? What is a keyway?

11. Draw carefully in full size the profile of a cam with minimum radius 25 mm. and having a knife-edge follower moving radially for the following motion: lift 20 mm. during 45° of cam rotation, dwell for further 25°, fall through 45° rotation and the remaining period is again dwell. Lift and fall take place uniformly.

12. Draw two involute gears of 20 and 30 teeth in mesh taking module as 5 mm. and pressure angle as 20°.

13. What is an assembly drawing ? What should it describe?

14. From your workshop take the measurements of a bench vice and draw an assembly and detail drawing of it.

CHAPTER 9

Architectural and Structural Drawings

9.1 Introduction

Architectural drawings deal with the construction and layout of buildings. An architect is one who properly arranges the layout of the rooms, corridors, doors, windows and staircases so as to secure the maximum of comfort and convenience with the best utilisation of the available space and materials.

Anything that serves to safely carry and transmit the loads coming on it is a structure. Structural drawings deal with the framework and details of the supporting members of buildings, bridges or other structures; e.g. foundations, columns, girders, beams, roofs and floors. A detailed structural drawing shows the arrangement of reinforcements, rivets, bolts, welds, stiffeners, brackets and cleats, and describes in short notes of the materials used and the nature of its construction and finish.

9.2 Styles of Lettering

The style of lettering in architectural drawings as already pointed out in article 3.2, is based on the Old Roman Style, Fig. 3.3, which is particularly used for titles of drawings of important buildings. Modern architects generally prefer to use simpler styles shown in Fig. 3.4. It is also the general practice, in architectural drawings, to use only vertical capitals, except where lower-case letters are accepted as standard international abbreviations. The Indian Standards permit the use of both vertical and sloping type of letters in architectural drawings.

The simple Gothic style of lettering, Fig. 3.2, is generally used in structural drawings.

9.3 Nomenclature of Homes and Buildings

A building is any fixed structure enclosing space; parts of such structures e.g. walls, columns, verandahs; balconies or roofs are also referred to as "building".

A building used for the residence of a family is a *dwelling*. A dwelling is considered as the *home* of a family, if the family resides in it almost on a permanent basis.

Buildings may be classified into four types:

(i) *Industrial Buildings*—e.g. factories, warehouses, laundries, distilleries.

(ii) *Business Buildings*—e.g. commercial offices, shops.

(iii) *Public Buildings*—These are places of public worship or public assembly, e.g., temples, churches, mosques, schools, colleges, cinema halls, hospitals, hotels.

(iv) *Residential Buildings*—i.e., buildings used chiefly for human habitation

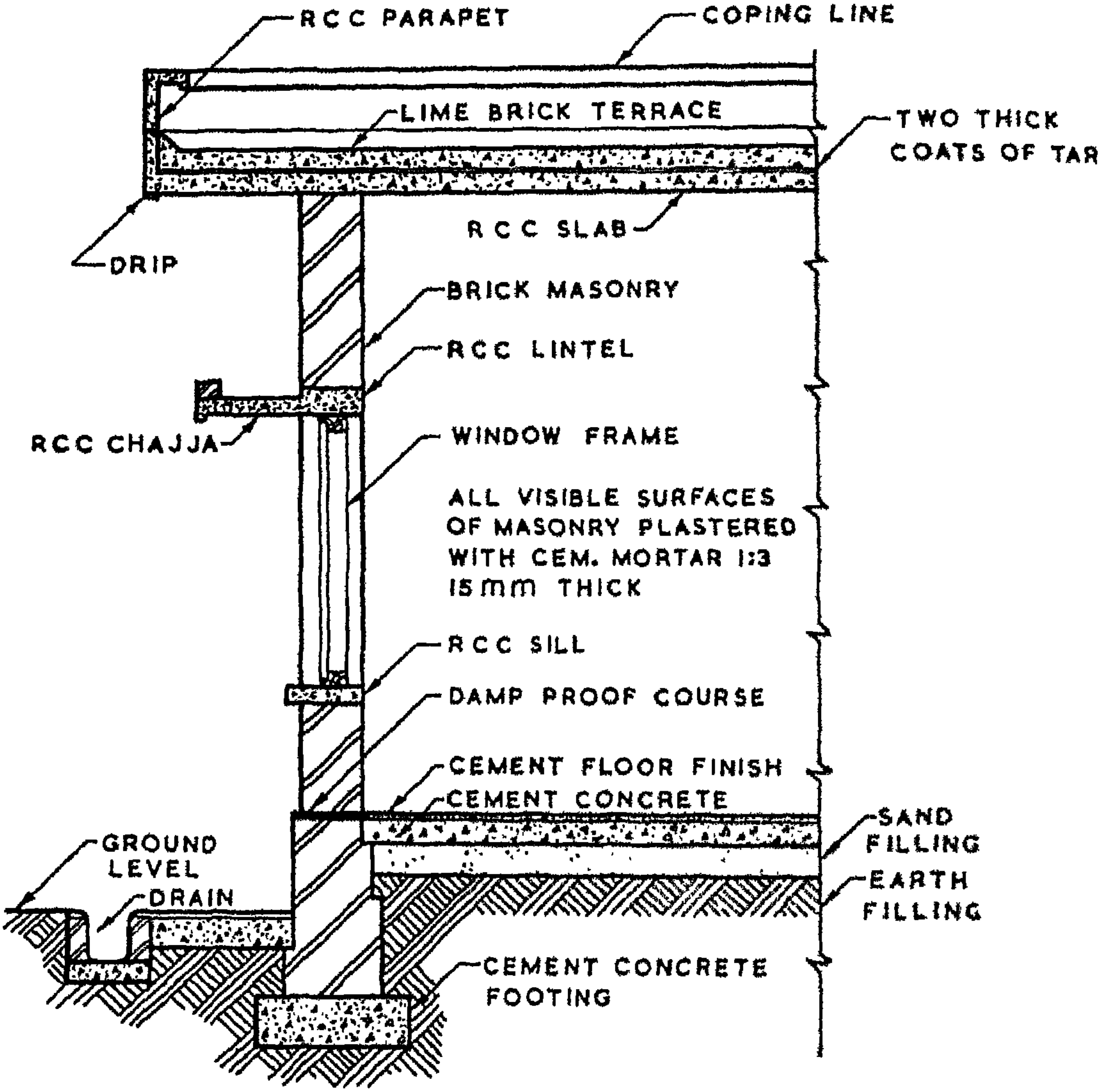


Fig. 9.1 Section through a building

and include garages, stables and other outhouses necessary for the main building.

The names of some important parts of a building are explained below and some are also shown in Fig. 9.1. The terms are arranged approximately in the order of their occurrence in a building.

Footing—The widened portion of a foundation to provide greater bearing area.

Foundation—The part of a structure below the lowermost floor which provides support for the superstructure and distributes the loads to the supporting soil.

Plinth—The part of building between the ground level and the floor first above the ground.

Damp Proof Course—A layer of material to prevent penetration of dampness or moisture from one part to another, of a building.

Floor—The lower surface of rooms and passages. The term is also used to indicate a storey, i.e., a set of rooms on one level. Ground floor means a storey nearest to ground level, first floor is a storey above the ground storey. The Indian Standards recommend that ground floor should be called "floor 1" (or storey 1) and first floor should be called "floor 2" (or storey 2) and so on; the first basement floor is designated as "floor 001" and the second basement floor, "floor 002" and so on. *Floor height* or *storey height* is the distance between the surface of any floor and the surface of the floor next above it, but when there is no floor above, it is the distance between the floor and the ceiling next above it.

Sill—A slab at the bottom of a window or door.

Lintel—A slab or beam at the top of a window or door to support the masonry immediately above it.

Chajja—A projecting slab over the openings in external walls to provide protection from sun and rain.

Ceiling—The surface at the top of a room, i.e. the bottom face of the roof slab or floor slab above. *Ceiling height* is the distance between the floor and the ceiling over it.

Beam—A horizontal member which supports loads; smaller beams are called joists.

Rafter—One of the sloping beams in the case of sloping roofs.

Girder—A relatively larger beam which supports other beams.

Roof—The top covering of a house or the top surface of the upper covering.

Parapet—A low wall projecting along the edge of a roof.

Stairs—A set of fixed steps connecting different levels inside a building; it is also called a *flight of stairs*; *stair* (singular) means one of the steps. A *staircase* is a set of stairs. A platform at the end of a flight steps is called a *landing*.

Baluster—A short pillar or post supporting a hand rail of a staircase or balcony. A *balustrade* is a row of balusters with a hand rail or coping.

Balcony—A horizontal platform including a handrail to serve as a passage or sitting out place. In theatres it means a set of seats in separate enclosures.

Coping—The topmost covering over a balustrade or parapet.

Drain—Any device like pipe, channel, or ditch for carrying off sewage and waste water.

Water Closet—A latrine with arrangement for flushing the pan with water.

Sink—A basin with an outflow pipe for the removal of dirty water.

Sewage—Refuse from houses and streets; a *sewer* is a drain carrying off sewage.

Concrete—A mixture of cement, gravel (or broken stone), sand and water which sets and hardens into a stony substance.

Mortar—A binding material in masonry, usually a mixture of lime (or cement) sand and water. When mortar is used to cover masonry walls and ceiling it is called *plaster*.

Masonry—Stone, brick or other similar building units laid up unit by unit, bonded together and set in mortar.

Reinforced Concrete—Concrete in which steel bars are embeded to resist outside forces causing tension in concrete.

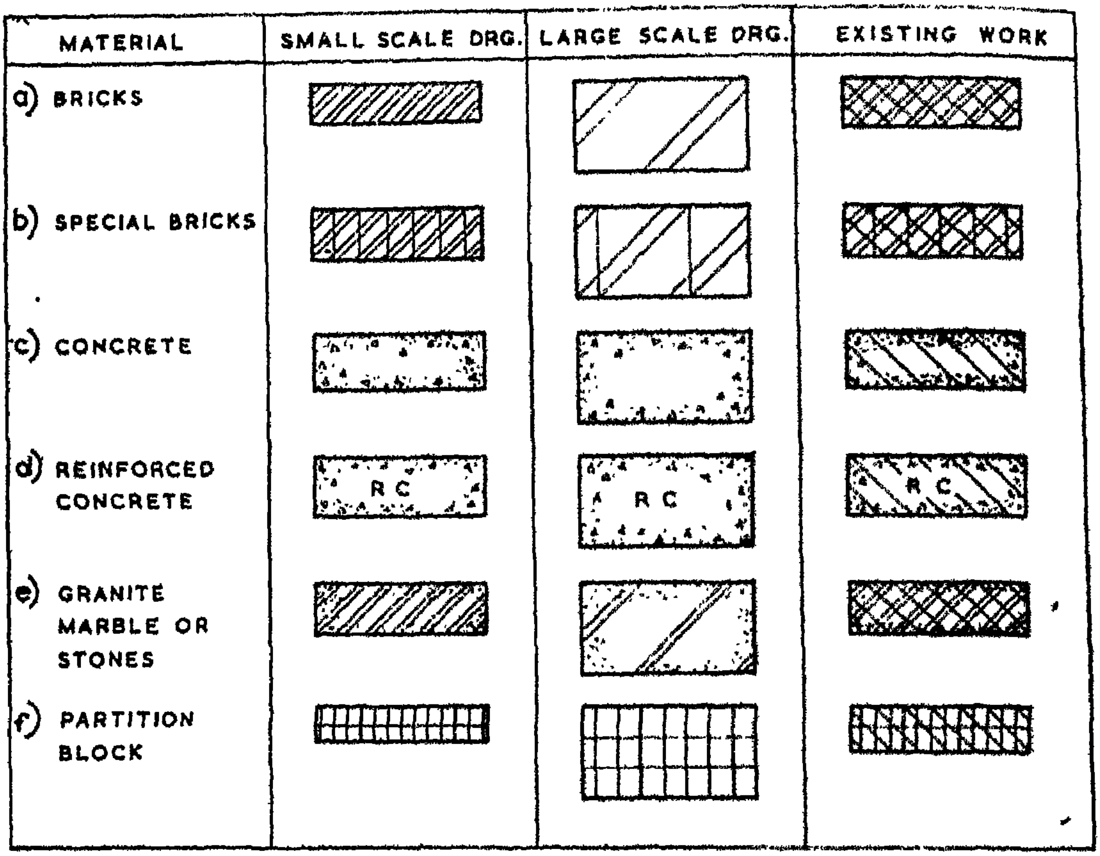


Fig. 9.2 Symbols for materials in section

9.4 Symbols for Building Materials

In sectional views it is necessary to distinguish between the various materials used in the construction of buildings. The recommended method of indicating the materials by hatching is shown in Fig.9.2. Where large areas of section hatching are to be shown, it is recommended that a portion near the edge only be hatched as in Fig. 9.2c and 9.2d. Very thin metal sections are blackened in solid, leaving a thin space between adajacent portions which are actually in contact, Fig. 9.3.

Other abbreviations and symbols become necessary to save time and space. Appendix I gives a list of such recommended abbreviations and symbols. *Abbreviations are* the same in the singular or plural.

9.5 Floor Plans and Elevations

The terms "plans" or "drawings" generally include all the necessary drawings for the complete construction of a building. The plans required are: (a) site plan, (b) floor plans, (c) cross-sections, and (d) elevations; and in the case of important buildings, (e) one or more perspective views and (f) a landscape plan are also required.

(a) *Site plan*—The site plan is drawn to a scale not less than 8 m. to 1 cm. (or 64 ft to 1 in.). It shows:

(1) the boundaries of the site showing its outline and length of each side,

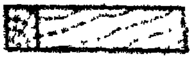
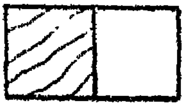
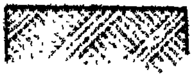
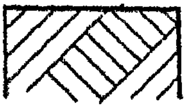
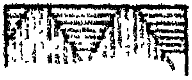
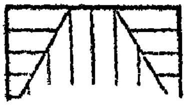
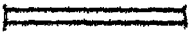
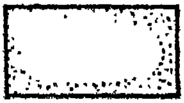
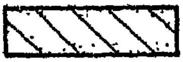
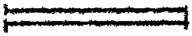
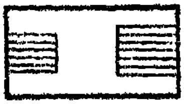
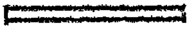
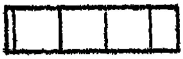
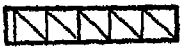
MATERIAL	SMALL SCALE DRG.	LARGE SCALE DRG.	EXISTING WORK
g) WOOD			
h) EARTH			
i) ROCK			
j) PLASTER			
k) GLASS			
l) FIBRE BOARD			

Fig. 9.2 Symbols for materials in section

the plot number and survey number;

(2) the plot numbers of adjoining sites;

(3) the position of the site in relation to the neighbouring streets; the nearest street and means of access to it; and the widths of the streets adjoining the site;

(4) all existing buildings standing on the site; and the exact location of the proposed building;

(5) the position and number of storeys of all other buildings within 12 m. of the site;

(6) the north direction and the direction of the prevailing wind;

(7) the dimensions of the space proposed to be left between the building and the boundaries of the plot on all sides;

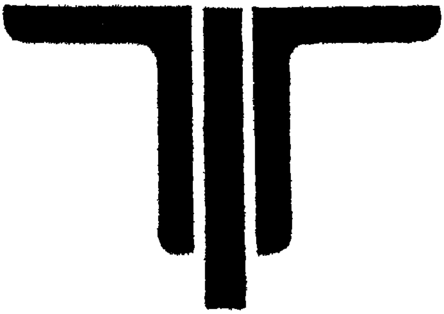


Fig. 9.3. Thin sections in contact

(8) the proposed drainage lines and the place to which they are finally carried;

(9) the direction and amount of surface slope; and

(10) the nature of soils in the trail pits dug near the proposed buildings.

(b) *Floor Plans*—The floor plans, one for each floor (if they are different), are drawn to a scale not less than 1 m. to 1 cm. (or 8 ft. to 1 in.). These are actually *sectional plans* at about the eye level and include:

(1) the general arrangement of different rooms and passages;

(2) the sizes and spacings of all supporting members and thickness of walls;

(3) the exact location of windows, doors, cupboards, and all other features that can be seen, e.g., water closets, sinks, baths and the like which may be indicated by appropriate symbols;

(4) position of beams and trusses and other important features that cannot be seen in the floor plan are indicated by lines made of short dashes (hidden lines), or adjacent part lines (dashes and dots alternatively); and

(5) the north line.

(c) *Cross Sections*—These are vertical sectional elevations through the building. The sectional plane is generally chosen to cut as many details as possible. These sectional views give:

(1) the details of materials of construction;

(2) the heights of windows, doors, cupboards, and ceilings;

(3) the depth and width of foundation, beams, walls and floors;

(4) the drainage and slope of the roof;

(5) the street and the ground elevations; and

(6) the details of staircases.

While drawing the cross-section, the architect imagines himself to be walking along the section plane line shown on the plan and records vertical lines of all the details from the roof to the foundations. Parts which are cut by the section plane are shown in section (hatched). The features beyond the section plane are also shown in elevation.

(d) *Elevations*—The elevations viewed from adjoining streets are important and should be pleasing to the eye.

(e) *Perspective Views* — Perspective views are true views as seen in a photographic camera. In perspective views a nearer object looks larger than a farther object of the same size; while in an orthographic elevation both the objects look alike in size. Thus an orthographic elevation is said be "flat" or lacking in "perspective"; and hence to help to visualize the true views of a building it is necessary to draw perspective views.

(f) *Landscape Plan*—The landscape plan gives the dispositions of the trees, plants, shrubbery, the hillocks, fountains, foothpaths, car-drives and the like which make the scenery surrounding the building beautiful.

PROBLEMS

1. What are architectural drawings?
2. Who is an architect?
3. What are structural drawings?
4. What styles of lettering are mostly used in architectural drawings?
5. Define a building.
6. State the four types of buildings.
7. Define the terms (a) footing, (b) foundation, (c) plinth, (d) floor, (e) ceiling, (f) coping, (g) beam, (h) girder, (i) chajja, (j) lintel, (k) sill, (l) parapet, (m) balcony, (n) baluster, (o) rafter, (p) roof, (q) drain, (r) water closet, (s) sewage (t) mortar, (u) plaster, (v) concrete, (w) reinforced concrete, (x) masonry, (y) sink and (z) a flight of stairs.
8. What are the symbols for the following materials in section (a) rock, (b) earth (c) wood, (d) brick masonry and (e) reinforced concrete?
9. How are thin metal sections in contact shown in drawings?
10. What are the standard abbreviations for (a) drawings, (b) centimetre, (c) millimetre, (d) centre line, (e) centre of gravity, (f) diameter, (g) diagonal, (h) department, (i) cross-section, (j) cubic inch, (k) cubic metre, (l) cubic centimetre, (m) door, (n) reinforced concrete, (o) micron, (p) kilowatt hour, (q) gram, (r) gravitational acceleration, (s) cast iron, (t) average, (u) centimetres, (v) millimetres and (w) second (of time).
11. What is the minimum scale for drawing a site plan?
12. What are the essential details required to be shown on a site plan?
13. What are the essential details required to be shown on a floor plan?
14. What are the essential details required to be shown on a cross-section?
15. What is the purpose of a landscape plan?

CHAPTER 10

Electrical Drawing

10.1 Electrical Drawing

Electrical drawings have a number of uses in their particular sphere. They convey in fairly exact detail the idea of an electric connection, circuit or installation. In the first place, the designer makes a drawing of the project in hand, detailing its general layout.

Later on, those who are carrying out the installation or doing repair jobs from time to time find it very convenient to refer constantly to this drawing.

These drawings usually do not supply details regarding the construction of individual elements. They show in a general way the elements by way of symbols and further illustrate the system of connections.

10.2 Graphical Symbols

It is common in electrical engineering practice to use graphical symbols. They stand for various means and devices used. They further illustrate diagrammatically the system of connections.

It may be necessary in detailed diagrams to show the physical structure of the apparatus, the actual positions of the terminals and other details. Where possible, however, standard symbols should be used. This in fact is the practice recommended by the Indian Standards Institute. Some of the graphical symbols are shown in Fig. 10.1 as recommended by the Indian Standards Institute.

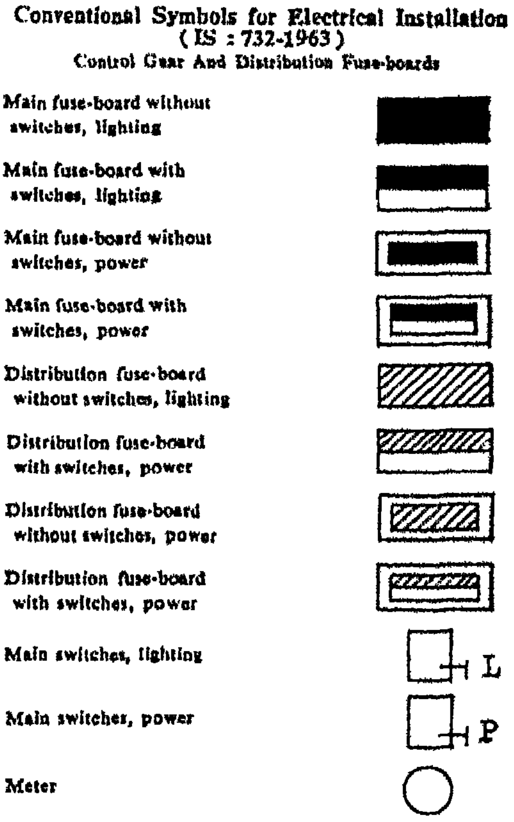

Conventional Symbols for Electrical Installation
(IS : 732-1963)
Control Gear And Distribution Fuse-boards
Main fuse-board without switches, lighting
Main fuse-board with switches, lighting
Main fuse-board without switches, power
Main fuse-board with switches, power
Distribution fuse-board without switches, lighting
Distribution fuse-board with switches, power
Distribution fuse-board without switches, power
Distribution fuse-board with switches, power
Main switches, lighting
L
Main switches, power
P
Meter

Fig. 10.1 Conventional symbols

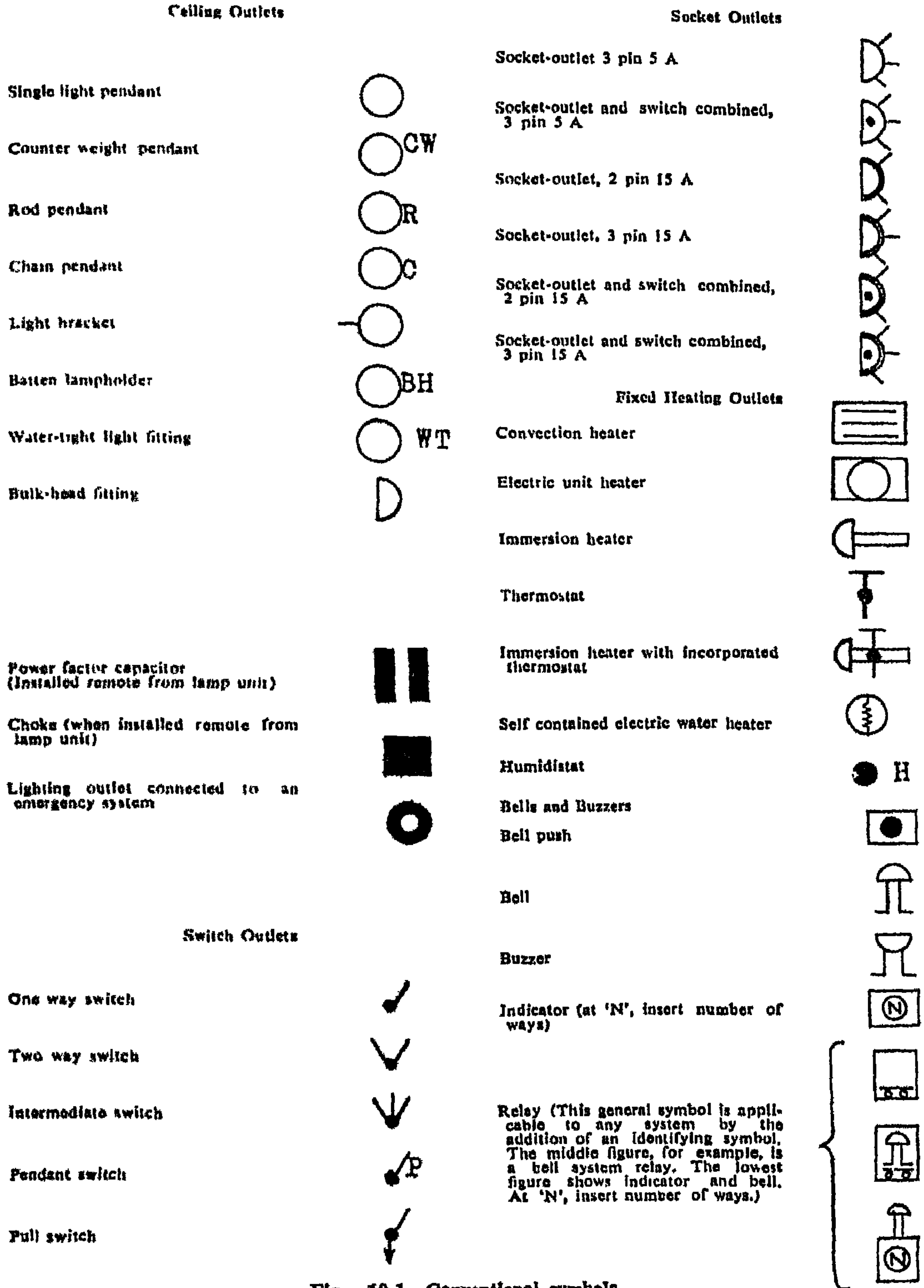

Ceiling Outlets
Single light pendant
Counter weight pendant
CW
Rod pendant
R
Chain pendant
C
Light bracket
Batten lampholder
BH
Water-tight light fitting
WT
Bulk-head fitting
Power factor capacitor (Installed remote from lamp unit)
Choke (when installed remote from lamp unit)
Lighting outlet connected to an emergency system
Switch Outlets
One way switch
Two way switch
Intermediate switch
Pendant switch
P
Pull switch
Socket Outlets
Socket-outlet 3 pin 5 A
Socket-outlet and switch combined, 3 pin 5 A
Socket-outlet, 2 pin 15 A
Socket-outlet, 3 pin 15 A
Socket-outlet and switch combined, 2 pin 15 A
Socket-outlet and switch combined, 3 pin 15 A
Fixed Heating Outlets
Convection heater
Electric unit heater
Immersion heater
Thermostat
Immersion heater with incorporated thermostat
Self contained electric water heater
Humidistat
H
Bells and Buzzers
Bell push
Bell
Buzzer
Indicator (at 'N', insert number of ways)
N
Relay (This general symbol is applicable to any system by the addition of an identifying symbol. The middle figure, for example, is a bell system relay. The lowest figure shows indicator and bell. At 'N', insert number of ways.)
N

Fig. 10.1 Conventional symbols

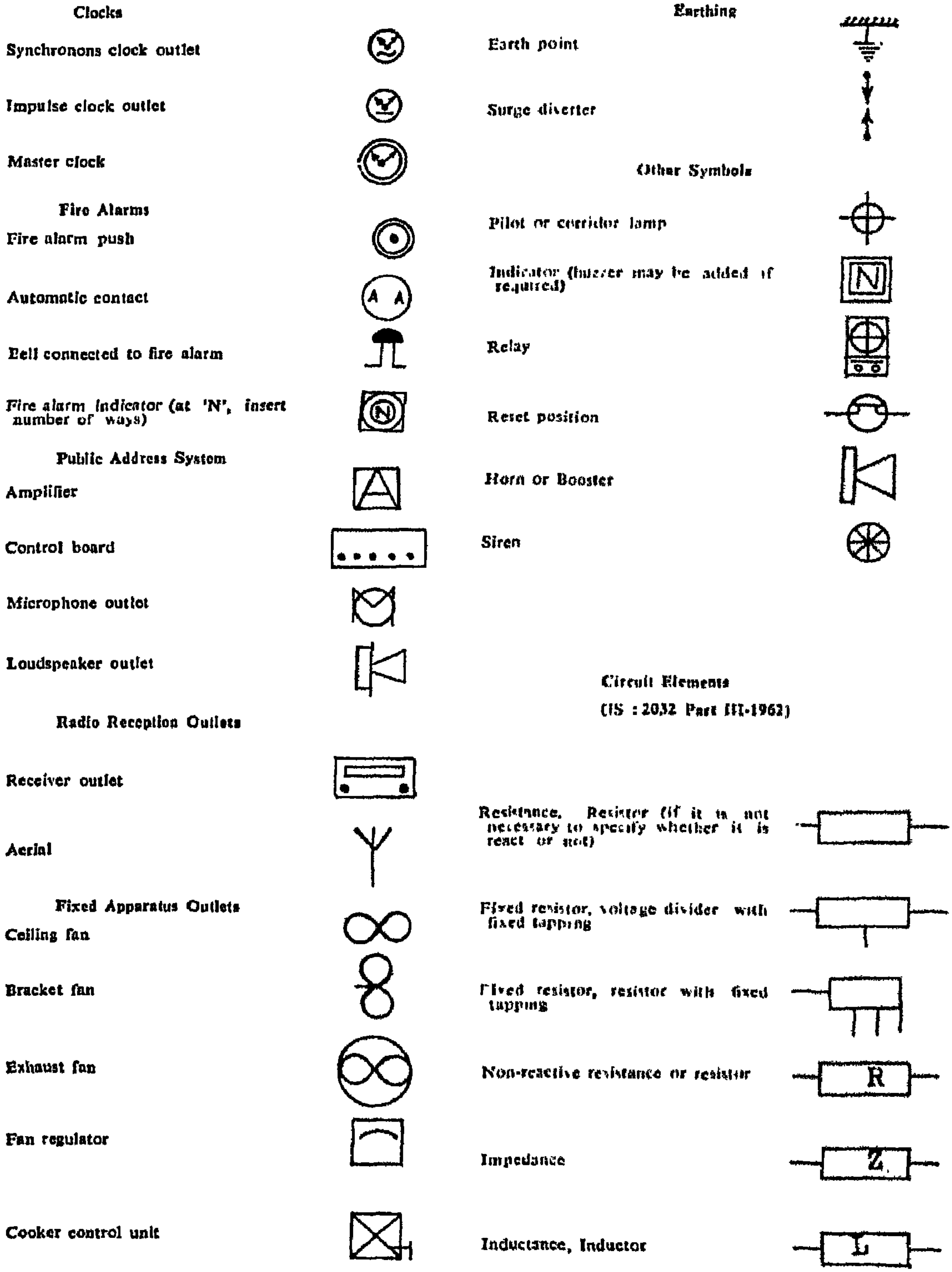
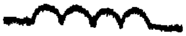
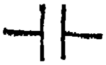
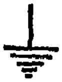
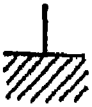
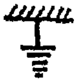
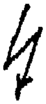
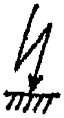
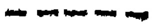
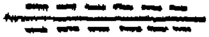
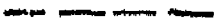
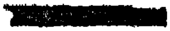
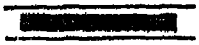
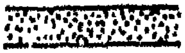


Fig. 10.1 Conventional symbols

Winding	
Capacitance, capacitor (the distance between the plates shall not be greater than one of the length of the plates)	
Earth	
Frame or chasis connection	
Frame or chasis earth connection	
Fault	
Example : Position of fault to frame	
Screen	
Example : Screened conductor or cable	
Mechanical coupling. (This form and also other forms of coupling like thermal coupling are expressed)	
Magnetic core	
Laminated core	
Dust core	

Variability

(IS : 2032 Part III-1962)

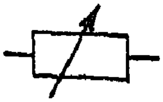
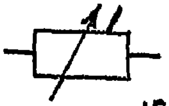
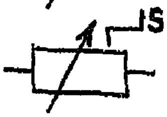
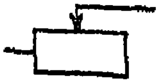
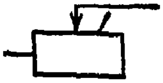
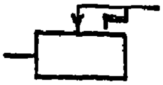
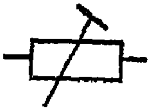
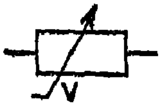
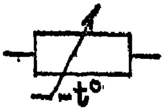
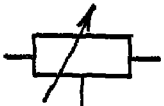
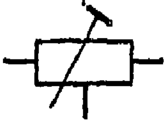
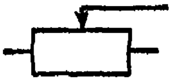
Variable resistor (General symbol)	
Continuously variable resistor	
Resistor variable in steps ('S' denotes number of steps)	
Variable resistor with moving contact	
Continuously variable resistor with moving contact	
Resistor with moving contact variable in steps	
Present voltage divider	
Voltage dependent resistor	
Temperature dependent resistor with negative resistor temperature coefficient	
Variable voltage divider	
Preset voltage divider	
Voltage divider with moving contact	

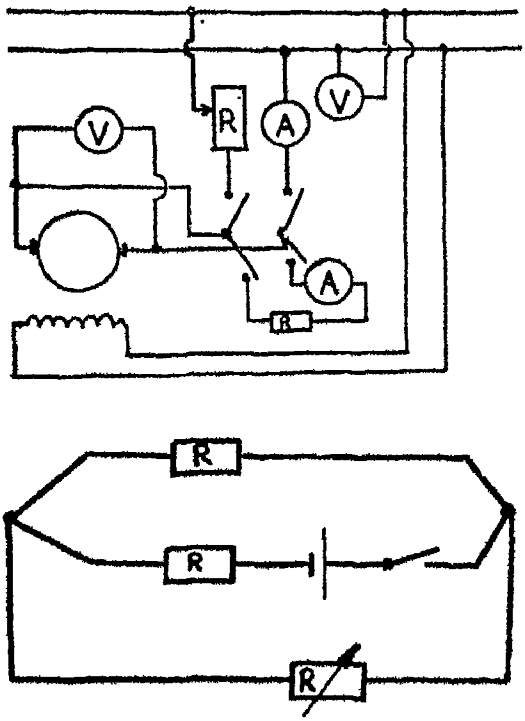
Fig. 10.1 Conventional symbols

10.3 Circuit Drawing

An electrical circuit is a system of conductors for the puropse of conveying electrical energy. Fig. 10.2 shows two circuit diagrams using conventional symbols.

10.4 Schematic And Pictorial Diagrams

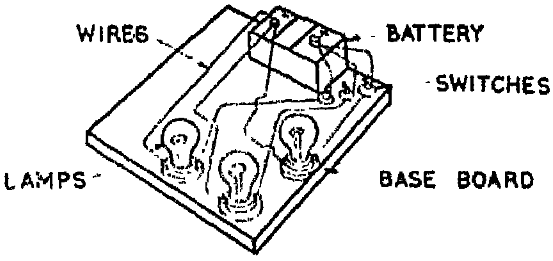
A pictorial drawing shows very much as a picture does, the essential elements of an electric circuit and the way they are connected to each other. No symbols are used and the elements look as they actually are.



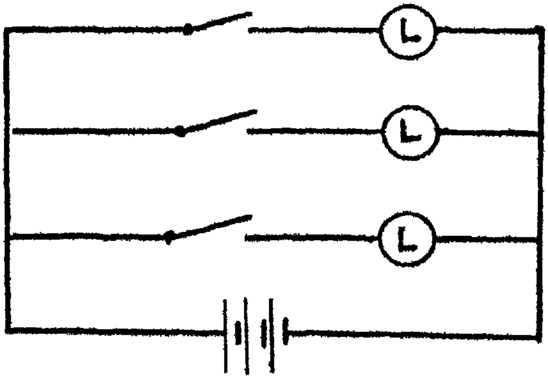
CIRCUIT DIAGRAMS

Fig. 10.2 Examples of circuit drawing

It is easy to read and follow a pictorial diagram, particularly when the circuit is simple.



PICTORIAL DIAGRAM



SCHEMATIC DIAGRAM

Fig. 10.3 Examples of pictorial and schematic diagrams

But a complex circuit where different kinds of electrical elements are used and interlinked in various ways, a pictorial diagram may not be very helpful. The details often look jumbled. They cannot be visualised or comprehended as clearly or exactly as one would like. Schematic diagram serves the purpose much better in such instances.

In a schematic diagram electrical symbols are used and the details of connections shown in a much simpler and neater way.

The schematic diagram is quite simple and easy to draw. It requires some practice to read it with ease, but it definitely helps towards a better understanding of the details. (Fig. 10.3.)

PROBLEMS

1. What is an electrical drawing?
2. What are pictorial and schematic diagrams of electrical circuits?
3. What are the advantages of conventional standard symbols and schematic diagram?
4. Draw the schematic diagram of a
   (i) series circuit
   (ii) parallel circuit
   (iii) torch light.
5. For what purposes is a pictorial diagram best suited?

CHAPTER 11

Reproduction of Drawings

11.1 Introduction

Reproduction of a drawing means multiplying the number of copies of any given drawing. The given drawing is the "original" and the reproduced drawings are termed "copies", "duplicates" or "blueprints" or simply "prints". Reproduction of drawings is necessary in almost all practical cases. The original drawings are valuable documents and should be carefully preserved for future reference. Thus only copies of the original drawings are used as working drawings. It is, therefore, necessary to use some rapid, exact and economical process for making the copies. Photographic methods are best suited for this purpose.

In the photographic method the original drawing is drawn on a transparent or transluscent medium, which may be either a tracing paper or tracing cloth. The drawings may be made in dark pencil or preferably in Indian ink. Duplicate copies are obtained on sensitized paper. That means, a paper which is coated with a chemical preparation. It changes its chemical composition and sometimes its colour by the action of light.

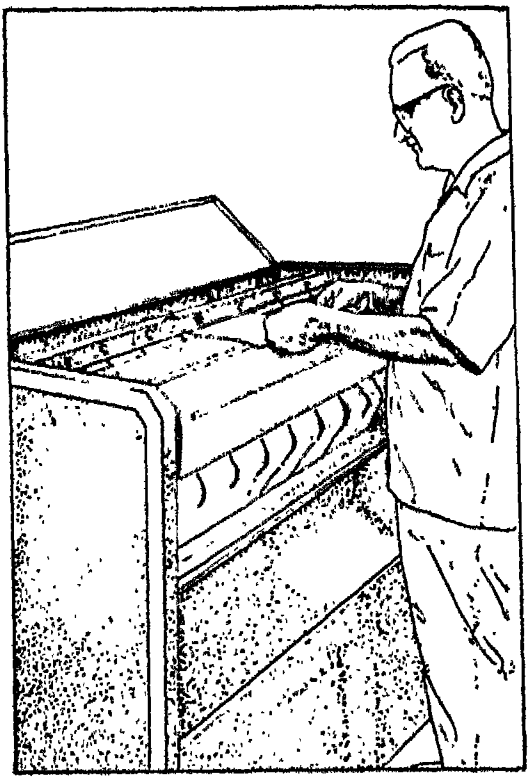


Fig. 11.0 Blueprinting machine

The sensitized paper is held in close contact with the original tracing in a printing frame with a flat glass top and is exposed to light in such a way that the light passes first through the glass, then the tracing and then falls on the sensitive side of the duplicating paper. Light cannot pass through the dark lines of the drawing, and so, those parts on the sensitized paper remain unexposed to light.

After some exposure the sensitized paper is developed or fixed or both developed and fixed, as the case may be, by dipping in certain chemical solutions and usually washed with water to clean off the chemicals and then dried. The unexposed parts of the paper, that is, the lines of the drawing itself and the background which is exposed get two contrasting colours, thus giving a print which is an exact replica of the original drawings.

There are completely dry processes too. In such cases the sensitive paper is never washed with water, and the developing or fixing is done by chemical vapours.

There are many methods of reproduction of drawings and only three most commonly used methods are described below.

11.2 Blueprinting Process

In a blueprint the background is deep blue in colour and the lines on it are white.

Blueprint papers are made by applying a coating of a solution of potassium ferricyanide and ferric ammonium citrate. These papers can be purchased in a ready-made form. The sensitive side of the fresh paper is usually of light greenish yellow colour. It gradually turns to a gray bluish colour if not kept carefully away from light.

The length of exposure depends upon the type of paper, the intensity of the light and also upon the age of the paper. The exposed blueprint paper is developed and fixed in plain water bath.

An alkaline solution destroys the blue colour of the developed print. Hence a 1.5 per cent solution of caustic soda may be used for adding white lines on a blueprint.

11.3 Ammonia Gas—Dry Development Prints

In this dry process, the paper is coated with a chemical of such nature that on exposure to bright light as before in a printing frame, the chemicals become practically colourless. The print is then put into a box containing fumes of ammonia vapour. The chemicals on the unexposed parts react with the vapour and give visible lines of some azodyestuff. These papers can be handled safely under normal indoor illumination.

11.4 Photostat Process

The two methods described above are known as *contact methods of reproduction*. The photostat process, on the other hand, is a *camera copy* process. A photostat print may be of the same size, or larger or smallar than the original, while contact prints must be of the same size.

In the photostat camera, the original drawing is photographed to the desired size, and the negative so obtained is developed and dried (no dark room is required). The negative has white lines against a black background. A positive print, having black lines against a white background is made by again photostating the negative print.

PROBLEMS

1. What is the meaning of reproduction of drawings?
2. Describe how a blueprint of a drawing is obtained.
3. What is a sensitized paper?
4. Describe a dry process of reproducing drawings.
5. What is a photostat process?

APPENDICES

I

List of Recommended Abbreviations and Symbols

Note :

1. Abbreviations are the same in singular or plural.
2. No period (i.e., full stop or comma) should be used unless the abbreviation becomes a full word in English (excepting mathematical abbreviations).
3. The use of lower case letters for abbreviations on *drawings* is discouraged, except for some internationally recognized abbreviations as given below.
4. It is always a good practice to give a key to the abbreviations and symbols used in the particular drawing, to avoid ambiguity.
5. The same symbol may stand for more than one term, if such usage is customary However, care should be taken to avoid confusion and misinterpretation.
6. In the following list, the symbol shown after a comma is an alternative.

Absolute	abs
Acre	ACRE
Across flat	A/F
Aggregate	AGG
Alternating current (adjective)	AC
Alternating current (noun)	a-c
Aluminium	Al
Ampere	A
Ampere-hour	Ah
Angle	angle, ∠
Angle (structural)	L
Annealed	ANL
Approved	APPD
Approximate	APPROX
Arrangement	ARRGT
Asbestos	ASB
Asphalt	ASPH
Assembly	ASSY
At	AT,
Average	avg
Beam	I, B
Bench mark	BM
Birmingham gauge	BG
Bitumen	BITN
Bottom	BOT
Break horsepower	BHP
Brickwork	BWK
Brinell hardness number	BHN
British thermal unit	BThU
Cast Iron	CI
Cast Steel	CS
Cement	CEM
Cement Concrete	cc
Centre of gravity	cg
Centre Line	CL
Centre to centre	C TO C, c/c
Centimetres	cm
Centimetres per second	cm/s
Chamfered	CHAMF
Channel	CHD

Checked	CHD
Circular pitch	CP
Circumference	cc
Coefficient	COEFF
Column	COL, C
Concrete	CONC
Copper	Cu
Corrugated	CORR
Countersunk	CSK
Crossing	X-ING
Cross over	X-OVER
Cross section	CS
Cubic centimetre	cm^3
Cubic foot	ft^3
Cubic feet per second	cusec
Cubic inch	$in.^3$
Cubic metre	m^3
Cubic millimetre	mm^3
Cubic yard	yd^3
Cylinder or cylindrical	CYL
Damp proof course	DPC
Degree (angle)	deg.,°
Degree, Centigrade	°C
Degree, Fahrenheit	°F
Department	DEPT
Detail	DET
Design	DSGN
Diagonal	DIAG
Diameter	DIA, ϕ
Diametral pitch	DP
Direct current (adjective)	DC
Direct current (noun)	d-c
Distance	DIST
Door	D
Drawing	DRG
Drawn	DRN
Elevation	EL
Embankment	EMB
Enamelled	ENAM
Engine	ENG
Expanded metal	XPM
External	EXT
Extra-high voltage	E-HV
Extruded	EXTD
Feet per second	ft/s
Figure	FIG
Finished floor level	FFL
Fire hydrant	FH
Flushing cistern	FC
Foot	ft
Forced draught	FD
Forged steel	FS
Formation level	FL
Gallon	gal
Gallons per minute	gal/min
Galvanized	GALV
Galvanized iron	GI
Glazedware pipe	GWP
Grease trap	GT
Gram	g
Gravitational acceleration	g
Ground level	GL
Gunmetal	GM
Hard drawn	HD
Hardened & tempered	H & T
Heavy	HVY
Height	HT, HGT
Hexagon of hexagonal	HEX
High flood level	HFL
High flood level, ordinary	OHFL
High flood level, maximum	MAX HFL
High tensile steel	HTS
High tensile welding steel	HTWS
High tension	HT
High voltage	HV
Horsepower	hp
Hour	hr
Hundred weight	cwt
hydraulic	HYD
Inch	In., "
India rubber	IR
Indian Standard	IS
Indicated horsepower	IHP
Infinity	∞
Inside diameter	ID
Inspection chamber	ICH
Intermediate pressure	IP
Intercepting trap	IT

Internal	INT
Internal combustion	IC
Insulated or insulation	INSUL
Kilogram	kg
Kilogram meter	kg m
Kilolitre	kl
Kilometre	km
Kilometre per hour	km/hr
Kilovolt	kV
Kilovolt ampere	kVA
Kilowatt	kW
Kilowatt hour	kWh
Latitude	LAT
Lavatory	LAV
Left hand	LH
Length	L, l
Litre	l
Level crossing	LC
Longitudinal section	LS
Low pressure	LP
Low tension	LT
Low voltage	LV
Low water level	LWL
Macadam	MAC
Machine	M/C
Machined	M/CD
Malleable iron	MI
Manhole	MH
Material	MATL
Maximum	MAX
Megawatt	MW
Metre	m
Meter per second	m/s
Microfared**	F
Microgram	micrg
Microhenry	H
Micron	μ
Mild steel	MS
Miles per hour	mph
Milligram	mg
Millilitre	ml
Millimetre	mm
Millimicron	m
Minimum	MIN
Minute (time)	min
North	N
Not to scale	NTS
Number	No.
Ohm	OHM
Ounce	oz
Outside diameter	OD
Paper insulated	PI
Parallel	ll
Pattern number	PATT, No.
Per	PER
Percent	PER CENT %
Perpendicular	
Pitch circle	PC
Pitch circle diameter	PCD
Plate	PL
Platinum	Pt
Pound	lb
Radius	R
Railway	RLY
Rain water pipe	RWP
Reduced level	RL
Reference	REF
Reinforced cement concrete	RCC
Required	RQD
Revolutions per minute	rpm
Right hand	RH
Rivet	RVT
Road level	Rd L
Rolled section	RS
Room	R
Round	RD
Round head	RD HD
Screwed	SCR
Second (time)	s
Sheet	SH
Shower bath	SB
Sink	S
Sketch	SK
Sluice valve	SV
Specification	SPEC
Specific gravity	sp-gr
Specific heat	sp-ht
Spigot & socket	S & S
Spot faced	SF

** is Greek letter ,, ,, (mu)

Square	SQ
Square centimeter	cm^2
Square foot	ft^2
Square inch	in^2
Square kilometer	km^2
Square metre	m^2
Square yard	yd^2
Standard wire gauge	SWG
Stop valve	SV
Switch	SW
Symmetrical	SYM
Tee	T
Temperature	TEMP, T
Tonne	t
Tongued and grooved	T & G
Traced	TCD
Transformer	TRANS

Under cut	U/C
Vacuum	V
Volt	V
Volume	vol
Vulcanized India rubber	VIR
Waste pipe	WP
Water closet	WC
Watt	W
Watt-hour	Wh
Weight	wt
White Metal	WH
Window	W
Wrought iron	WI
Yard	yd
Year, annum	yr, a

II

Glossary Of Technical Terms

Aggregate	Broken stone or gravel is known as coarse aggregate, sand is called fine aggregate. These are used in cement concrete.
Allowance	The clearance between mating parts.
Anchor Bolts	Long bolts used to fix steel columns to foundations or truss ends to masonry walls.
Angle (structural)	An L-shaped metal bar.
Anneal	A process of heating and slow cooling to remove internal stresses.
Arch	A structure in the form of an arc carrying loads over an opening.
Asbestos	An incombustible fibrous mineral substance used for fire proofing.
Assembly Drawing	Drawing of a complete machine or tool in which the component parts are key numbered for identification.
Attic	The space directly below the roof of house.
Axle	The cylindrical bar (shaft) at the centre of a wheel.
Base	The bottom supporting part of a structure.
Basement	The storey below the ground floor.
Batten	Strip of wood.
Batter	A slope indicated as the horizontal displacement relative *to* a certain vertical distance; e.g. 1 to 4, or 2 to 1.
Beam	A horizontal member to support loads over an opening.
Bearing	(1) Support for a rotating shaft. (2) Any supporting area.
Bearing Plate	A flat piece of wood or metal used to distribute the load coming on it.
Bench Mark	A point of standard reference from which all other levels are counted.
Bevel	An edge with a slanting surface.
Blueprint	A drawing printed and developed on a sensitized paper by exposure to light.
Bolt	A cylindrical piece of metal with a head at one end and the other end threaded to receive a nut.

Bore	The inside diameter of a pipe or hole.
Boss	A raised flat projection above the general surface.
Burr	Rough projecting edges on a work piece resulting from cutting or punching.
Bushing	A replaceable lining of relatively soft material for a bearing or for a jig.
Cantilever	An overhanging structure supported at one end only.
Cam	A shaped plate which rotates about an eccentric axis to convert circular motion into reciprocating motion.
Chamfer	To make a narrow strip of sloping surface to prevent a sharp edge of any solid; to bevel an edge.
Channel	A metal section in the form of a rectangle with one side open.
Clerestory	A window above roof of the adjacent rooms to allow air and light.
Collar Beam	A beam typing opposite rafters or a sloping roof.
Column	A load bearing vertical member.
Concrete	A mixture of sand, broken stone, cement and water which can be easily moulded into any form when fresh, and which sets and hardens into a stony substance after a few hours.
Counterbore	To enlarge the top portion of a hole in the form of a cylinder.
Countersink	To enlarge the top portion of a hole in the form of a cone.
Dado	Lower part of room wall, coloured or decorated.
Detail Drawing	A drawing which describes fully each component part.
Die	A tool of hard steel used to cut external threads on a cylindrical piece.
Dowel	A cylindrical projection of wood or metal used for locating and holding together two split portions of a mould.
Drift	A piece of conical or wedge shaped steel.
Drill	(1) To make a cylindrical hole by a rotating tool. (2) A tool for making cylindrical holes.
Eave	Projecting lower edge of roof beyond the outer wall.
Elevation	(1) The height of a point above sea-level or other reference point. (2) The front view (in orthographic projection); side views are called side elevations.
Ferrule	A metal band in the form of a ring or cap around the end of a wooden handle to stick.
Fillet	A rounded concave surface connecting two surfaces meeting at an angle.
Firebrick	A special brick made of fireclay to resist heat or fire.
Fit	Degree of tightness between mating parts.
Fitting	Any small mating part that can be fitted on to another part; e.g. pipe fittings.

Fixture	(1) An electric or plumbing item fixed permanently in definite location. (2) Anything fixed rigidly to a machine for holding the work in correct position for the cutting tools.
Flange	The horizontal parts of an I-beam or channel. A projecting flat portion at the end of a pipe to make connections.
Flashing	Sheets of non-corrosive metal used to seal building joints from weather.
Flue	A chimney opening.
Footing	The lower part of a structure which rests on ground.
Forge	(1) A fireplace used by a blacksmith. (2) The shaping of hot metal by hammering or squeezing.
Foundation	The supporting wall or structure below the ground level.
Frame	The skeleton of a structure consisting of only main load bearing members.
Frog	A hollow in the bedding surface of a brick to provide a key for mortar.
Gable	Triangular end walls supporting a sloping ridged roof.
Gable Roof	Roof that slopes from two parallel walls with a ridge in the middle.
Gasket	A packing for a joint or between sliding parts.
Girder	A relatively larger beam which supports other beams.
Gradient	Slope indicating unit vertical displacement in certain horizontal distance; e.g. 1 in 25, or 1 in 100.
Guide Lines	Light lines drawn to guide the height of lettering.
Gutter	A trough or channel to carry off rain water.
Head-Room	Vertical distance between floor and ceiling or underside of beam.
Hip Rafter	The rafter at the junction of two sloping roofs forming a sloping ridge.
Hip Roof	A roof that slopes up from the four walls of a room.
Hopper	A funnel in the form of a frustum of a pyramid.
Horizon Line	In perspective drawing, a line, parallel to the ground line, at the level of the vanishing point.
Hub	The central portion of a wheel.
Isometric Projection	A pictorial projection in which the projections of the three principal axes of an object are inclined at 120 degrees to each other.
Jack	A tool for raising heavy loads by means of a screw or hydraulic pressure.
Jamb	The vertical sides or wall openings; also the vertical posts fixed to the vertical sides of wall openings.
Jig	A device which holds the work piece temporarily for guiding drills or other tools.

Joist	Small wooden or steel beam for supporting the floor or roof.
Key	A connecting piece of steel for attaching a pulley or gear wheel to its axle (shaft).
Landing	A platform at the top of a flight of stairs.
Lavatory	A place for washing face and hands.
Legend	(1) Key to symbols used. (2) Title or brief description of a drawing.
Line Diagram	A scale drawing showing only the centre lines of the walls of the object.
Lining	A covering on the interior surface.
Lintel	A slab or beam over an opening to support the wall above.
Load Bearing Wall	Wall supporting the roof or upper floors.
Longitudinal	Lengthwise of an object.
Louvre	An opening covered with a slotted screen, that keeps out rain and allows ventilation.
Lower Case	The small letters of the alphabet.
Machine	A device which transmits energy from one point to another.
Manhole	An opening in a boiler, pipe, sewer or other structure to permit a man to enter for cleaning or inspection.
Masonry	Structure built in brick, stone or other similar material which are laid up unit by units bonded together and set in mortar.
Mating Parts	Parts that fit together; e.g. shaft and bearing, bolt and nut.
Mechanism	An essembly of rigid members which permit desired relative motion between its members.
Member	Any component unit of a structure or mechanism.
Mortar	A mixture of sand, cement (or lime) and water, used for bonding.
Multiview Drawings	See orthographic projection.
Niche	A recess or hollow in a wall.
Nominal Size	Approximate size, not actual size.
Oblique Projection	Projection in which the front face of the object is parallel to the frontal plane and the projectors are parallel but inclined at any angle other than 90 degrees. If the projectors are inclined at 45 degrees on the drawing, the view is called a *cavalier projection.*
Orthographic Projection	A projection of an object in which the projectors are at right angles to the plane of projection.
Partition	An interior wall that divides space.
Perspective Projection	A method of single planar projection which represents an object as it appears to the eye (a picture as seen in a photographic camera).
Picture Plane	An imaginary plane used for projecting the picture of an object.
Pier	A vertical masonry support.

Pinion	The smaller of two gear wheels (toothed wheels) which work together.
Pilaster	(1) A horizontal sectional view of a building at about the eye level when the observer is standing on any floor. (2) Top view.
Plinth	The portion of a building between the surrounding ground level and the surface of the floor first above the ground level.
Plaster	A mixture of lime (or cement), sand and water used as a protective decorative coating for walls and ceilings.
Prime Coat	First Coat of paint (used to fill the pores of the surface).
Projector	A line (visual ray) assumed to be drawn from the observer's eye to any point of the object; the line of projection.
Purlin	A horizontal member spanning across trusses to support the roof.
Quoins	Corner stones at the corners of masonry walls.
Rafter	An inclined beam to support the roof.
Ream	To enlarge or finish a hole.
Rib	A rod-like projection on a surface for strength.
Ridge	The top edge where two sloping surfaces meet.
Shaft	A cylindrical bar used to carry pulleys for transmission of power.
Sill	A slab or beam at the bottom of a door or window frame.
Soffit	The underside of an arch or other overhandling structure.
Specifications	The written description of the processes of the work to be done and of the type of materials to be used in the work.
Structure	A framework that supports loads without relative movement of its parts.
Stucco	Plaster covering for walls.
Tap	A tool for cutting internal threads.
Technical	Quality belonging to a specialized art, science or craft.
Temperature	A heat treatment for tools which gives them the desired degree of hardness.
Template	An accurate pattern for laying out or checking the shape or size of a work.
Terrace	(1) A flat roof top. (2) A raised level platform of earth. (3) Ground or structure that rises stepwise.
Terrazzo	Floor constructed with marble chips mixed in cement mortar, ground to smooth finish.
Tolerance	The permissible variation of a dimension of an object.
Tracing	A copy of a drawing on a transparent paper or cloth used for reproduction of drawings.
Truss	Metal or wooden framework acting as a beam or girder for supporting loads of roofs or bridges.

Valley Rafter	A rafter forming the bottom support in a valley formed by two sloping roof surfaces.
Vanishing Point	A point to which the horizontal lines of a drawing appear to recede.
Veneer	A layer of decorative covering material disguising the interior material.
Washer	A flat metal plate with a hole larger than the bolt, used to provide a good seating for the head or nut of the bolt.
Web	A thin plate-like projection on castings for strength.
Working Drawing	A drawing containing detailed information to guide the workmen in the construction of a structure, the manufacture of a machine part, or in the assembly of a machine.

III

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